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ABSTRACT

A computer-assisted instruction (CAI) project undertaken in 1965 sought to: 1) teach college instructors to prepare quality CAI curricula; 2) ascertain student attitudes toward CAI; 3) compare CAI with the lecture method; and 4) demonstrate prototypical CAI courses. Teachers were successfully trained in the use of Coursewriter and prepared courses in audiology, mathematics, engineering economics, and cost accounting. Posttests administered to small groups of students who took the courses revealed that both performance and attitude correlated positively with aptitude, although the attitude measure was more likely a function of performance than a reaction to CAI as a method. Since aptitude correlated with criterion-referenced achievement, the goal of maximum criterion achievement for each student via individualized CAI was not attained; likewise, since the number of errors made by students correlated negatively with posttest scores, it appeared that the remedial branches were not serving their intended function. The high incidence of substantially correct answers entered improperly showed the need for building complex answer processing capabilities into the computer. (PB)

Dr. Hall
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C·A·I

**COMPUTER ASSISTED INSTRUCTION LABORATORY**

**COLLEGE OF EDUCATION · CHAMBERS BUILDING**

**THE PENNSYLVANIA STATE UNIVERSITY · UNIVERSITY PARK, PA.**

# The Development and Presentation of Four Different College Courses by Computer Teleprocessing

Interim Report
June, 1965

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# The Development and Presentation of Four Different College Courses by Computer Teleprocessing

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# CHAPTER I

# INTRODUCTION

Americans are bombarded almost daily by books, magazines, newspapers, television, and radio on the subject of the impending crisis involved in extending our educational resources to cope with expanding and changing education and technology. The crisis and its special implications for higher education are documented by the American Council on Education (see Venn, 1964). The curriculum development, research, and dissemination activities undertaken in the present project represented an attempt to point a way toward an alleviation of a portion of this educational crisis.

Our total educational effort in the United States is faced with a number of major challenges. One of these comes from the mushrooming growth of the school population at all educational levels, which has resulted in a nationwide shortage of teachers and instructional facilities. The indications are that this inadequacy is likely to persist for some years. However, the problem is more difficult than that associated with the mere expansion of present educational effort. A major problem is associated with the change in the job that schools and colleges are being asked to perform for society; changes in the society itself which educational institutions serve are increasingly dramatic and complex. The situation may be summarized by saying that at a time when the educational enterprise is being asked to expand itself, both with regard to personnel and instructional facilities, at the greatest rate in all history, it is at the same time being asked to increase the breadth, the depth, and the scope of education.

In attacking the problems of education, the first encountered difficulty is that the total resources available for educational development are quite limited relative to the magnitude of the task to be undertaken, which society regards as important. Thus, it is necessary to accept progress toward these goals as less than would be desired under ideal conditions, and to recognize priorities of greatest importance as primary tasks. The difficulties go well beyond the mere resource allotment in a monetary sense. In order to get a feeling for the extent to which this is true, it is well to consider specifically the nature of ideals which are becoming generally accepted for future public education in this country: (1) the length and scope of education freely available to each person in the entire population are to be extended as soon as feasible to encompass all of the education that will benefit a person;[1] (2) no significant fraction of the population should receive an education which can be regarded as being of poor quality; (3) education is a major process continuing throughout the life of the individual.

If one considers these ideals as goals, it becomes apparent that there are greater impediments to attaining some of them than the difficulty of obtaining the very substantial economic resources required. As a nation, we can no longer afford the luxury of merely trying to do more of what we have been doing in the past. Thus, the decision to increase significantly the content of education at all levels has very far reaching implications for the in-service education of teachers.

Perhaps the greatest difficulties of all do not arise directly from the requirements being placed on educational institutions, but stem from changes in the character of society itself. Surely, the most important single socio-economic phenomenon of the present era is the rapid shift from an economy based on limited-skill labor to one which rests on intelligent personal service of an increasingly technical nature. Moreover, at a time when jobs are becoming increasingly technical, it is also true that the technical competence required of workers is changing at an accelerating rate. In many vocational and professional areas today, the rapidity of technical and scientific advance has become so great that it is literally impossible to create academic curricula which are not obsolete at the time of their inception.

In a sense, the problem of the rapid obsolescence of curricula arises whenever the period of significant technological change is comparable to, or shorter than, the period required to train the majority of those who must teach the material. The accelerating pace of technological development implies that such conditions are going to become more and more general until they impact education across the board. It follows then that the methodology of education, the concept of teacher training, and the general structure of education must all be expected to undergo the significant and drastic changes in the near future. The widespread demand for the use of greater intelligence in the world of work is complicated by the need for more functional learning and understanding on the part of a mushrooming white collar society.

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[1] Cf. Policy Statement on education issued by President Johnson on November 4, 1964, " . . . every child has the right to as much education as he has the ability to receive. I believe that this right does not end in the lower schools, but goes on through technical and higher education, if the child wants it and can use it. . . ."

Indeed, the greatly increased technical content of job requirements, the correspondingly longer training periods needed to attain a given level of training, and the ever-changing character of the subject matter, already are imposing great burdens on existing efforts in education and are creating an impetus for change in the methodology and structure of instructional processes.

Clearly, new methodologies and techniques of education are of great importance where they seem capable of overcoming these fundamental difficulties. The technical approach which has been the focus of this investigation may be described as computer-assisted, teacher-supervised, self-study, and hereafter referred to as computer assisted instruction (CAI). There were a number of reasons to suggest that this approach might be fruitful: (1) potentially, it permits an efficient use of expensively and highly educated teachers, and thus a substantial increase in the student-to-teacher ratio; and (2) at the same time, it makes possible an acceleration and individualization of instruction to an extent which has often been dreamed in theory, but rarely achieved in educational practice.

Specifically, the objectives of the project were as follows:

1. To determine the feasibility of using college teachers with limited knowledge of digital computer systems and computer programing to prepare various subject matters for presentation by the computer. The teachers were aided in the preparation of these materials by the use of a special computer language developed especially for teacher-authors. This language, known as Coursewriter, allows an author to program the computer to present materials on the basis of the students' responses by the use of a relatively small number of logical commands. One purpose

of the project was to suggest improvements in the author language on the basis of actual author experiences. An anticipated outcome of the project was a more efficient special computer language for course writing by teachers. In addition, the feasibility of teaching several different subjects simultaneously by means of the computer was an important part of this objective.

2. A second objective was to ascertain the reactions of students to the course materials presented by computer-assisted instruction. Authors were encouraged to try out alternative teaching strategies in CAI so that preliminary evidence could be obtained to determine which methods of presentation would be most acceptable to the student. No attempt was made to undertake large-scale evaluations using large samples of students; however, preliminary student data for approximately 80 college students are reported in Chapter IV (p. 73).

3. A third objective was to make rough comparisons of the effectiveness of the computer presentation of course materials with the lecture-discussion method. No systematic comparisons of CAI and conventional lecture presentation were made; however, some informal comparisons were made to help evaluate the quality of the CAI materials. These preliminary comparisons did not involve full-length courses, but were confined to sections of the courses. The principal investigators question the value of a methodology consisting of teaching methods comparisons. Rather than attempting to "reject the null hypothesis" with regard to comparisons of CAI with traditional instruction, it was expected that such comparisons would help improve existing course materials and help identify a rationale for integrating sections of CAI courses with existing curricula. If CAI is to be an important educational medium in the future, the situations in which its use is most desirable must be quickly identified as well as the methods for best integrating it into the general educational process. The experiences of the teacher-authors reported in a later section of this report bear on the above question. In addition, several researchable problems related to the use of CAI, and methodologies for such research have been developed as part of the present project. Although full-fledged experiments have not as yet been undertaken, some pilot studies have been completed.

4. A fourth objective was to provide demonstrations of a functioning prototype of a computer-assisted instructional system which could be expanded to provide tutorial service to an entire school or group of schools. Dissemination of information is a serious problem in educational research. By means of live "hands on" demonstrations, and video tape recordings of students working with CAI, the investigators hoped to make some inroads into the problem of dissemination.

5. A fifth objective of the project was to determine the feasibility of a computer-assisted instructional system in which course material and student responses are teleprocessed over some distance between teaching terminals and a centrally located computer. While the chief purpose in teleprocessing in the present project was to eliminate the need for an expensive computer system and programing support, there are educational situations in which remote instructional terminals might be the most desirable feature of a CAI system. One such application would be a continuing education program, such as updating the training of graduate engineers. Another application which the investigators expect to explore in Pennsylvania is the use of CAI materials for the in-service education of elementary school teachers.

6. The sixth and final objective was to develop CAI curricula of sufficiently high quality to be used in later research studies with actual college and high school students. While the primary purposes of the investigation were the five listed above, CAI offers many opportunities for research on problems of complex human learning and instruction. A computer-controlled instruction system offers opportunities for carefully manipulated presentation of verbal stimuli and instructional materials rarely possible in previous research on instruction. The courses were developed in such a manner that they are readily amenable to experimental manipulations and research on student learning. A number of investigations have been proposed, and the results of several pilot investigations are located in Chapter IV (p. 73) of this report.

# CHAPTER II

## DESCRIPTION OF THE COMPUTER-ASSISTED INSTRUCTIONAL SYSTEM AND RELATED LITERATURE[1]

Computer assisted instruction may be thought of as a way to enhance the effectiveness of teachers and the teaching process through technology. In the past, devices such as motion pictures, filmstrips, workbooks, and language laboratories have been incorporated into educational practice to facilitate and extend teaching; generally, these devices have been used to automate traditional methods of teaching and not necessarily to make learning more functional. Regardless of the device, the general approach here has been to maintain the traditional method of teacher-mediated group instruction in the more or less conventional classroom situation.

The publication of Skinner's Science paper in 1954 set forth an alternative approach to the achievement of educational goals. Programed instruction specified desirable terminal behaviors and used the principles of a learning theory to establish a means of attaining these behaviors. The learning sequences in Skinner's plan were individualized in linear programs through self-pacing, or more recently in branching programs through the formulation of different sequences on the basis of a student's last response. Early in the movement, machines were fabricated to present these programed materials; however, it was found in most cases that the use of hardware did not enhance learning over the use of the same materials in text form (Goldstein & Gotkin, 1962).

Research and development involving the use of a computer to assist in the instructional process may be thought of as being related to teaching machine technology; but, CAI, because of its flexibility, decision logic characteristics, and sophistication of input-output modes, must be considered as a quantum advance over traditional programed instruction. Projects using a computer for instruction are similar to each other but differ in their emphasis. The flexibility of the digital computer allows for a variety of themes different from and richer than the themes of programed instruction as represented in the programed text or simple teaching machine. One such theme has been the use of sophisticated input and output displays to facilitate communication between the student and the system, e.g., cathode ray tube display, various large capacity random access visual and audio devices, special response keyboards, light pens, etc. These special interfaces between learner and computer are no doubt necessary with children and certain adult populations (blind learners, for example), but probably are not essential with most adults. They are particularly attractive to the psychologist interested in research, but at the same time do not stimulate similar research in other laboratories because the equipment used is generally of experimental or prototype construction and it is extremely expensive. Two efforts that emphasize this theme in computer teaching are those of Bitzer (1962, 1964) and Suppes (1964).

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[1] The investigators are indebted to Dr. E. N. Adams for the basic analysis of the field as contained in this chapter.

A second theme has been to adapt course organization to individual student's needs. Here the concept is to monitor and analyze student performance; and, on the basis of this performance plus other historical information about the individual student, continually adjust the course organization to optimize it for a particular student's progress. Such tailoring of materials to an individual student is highly desirable but of relative high cost because considerable computer capability would be needed for each student. To some extent, this has been the approach taken by Stolurow (1963) and Smallwood (1962).

A third theme has been that of tutorial interaction. The concept here is that the high-speed logic of the computing machine reacts to the detailed features of student performance on specific tasks, records the efforts of the student in dealing with these tasks, and presents appropriate remedial or accelerated action where the student is not succeeding or is insufficiently challenged. The tutorial interaction is supplementary to the strategic job of adjusting the arrangement and difficulty of the tasks and their manner of presentation to the individual student. This approach is exemplified by the effort at the IBM Research Center (Uttal, 1961, 1962).

A fourth theme has been the process of simulation and gaming interaction between the student and the machine. Here the role of the machine is that of simulator of a process or as an opponent with which the student interacts just as he interacts with process or persons in laboratories or real situations. This theme is prominent in the work at Bolt, Beranek and Newman, Inc., (Swets, 1962) and Wing at the Board of Cooperative Educational Services, Westchester County (N.Y.) Public Schools.

In addition to the above studies, the reader may find the review by Dick (1965) helpful in providing additional background in the development and status of computer-assisted instruction.

The present investigation of computer-assisted instruction emphasized tutorial interaction and made limited usage of the other themes described. The writers believe that each of the emphases described above represents a valid conception of an approach to the use of computers as educational aids, but that the tutorial approach may be the most practical. Current and projected needs forced the investigators to consider computer instructional cost, both for the development of courses and the administration of these courses by the computer in "production" teaching. The investigation sought to establish a flexible interface between the learner and the computer, but at the same time to utilize a system that would be justifiably economical in the long run to allow for wide-scale adaptation to a variety of educational operations.

The main outcome of the present project was the development of four college courses for presentation via CAI. Unlike most developmental projects in CAI, the present project was not concerned with the invention of terminal hardware or the writing of computer programs in machine language. These tasks have been avoided by using a commercially available typewriter terminal as the interface between the computer and the student, and the Coursewriter language developed at IBM's Thomas J. Watson Research Center for controlling this interchange. Virtually all of the efforts of the project have been devoted to the preparation of educational materials to be presented by the computer.

The Coursewriter language enables an author, with a minimum of special training, to include questions, problems, assignments, correct answers, incorrect answers, provisions for unanticipated answers, knowledge of results, and branches or alterations in the sequence of his course. In addition, an author can employ a process of recordkeeping known as Student Records, which will record and accumulate in storage all student responses and response times. This latter feature is useful to authors for the purpose of analyzing and improving the course content, in revising early trial versions of the course, and as a basis for counseling and advising students who were using the course material. Additional operations in Coursewriter can call for the presentation of visual material stored on 2 x 2-inch slides or audio material stored on magnetic tape at the student's terminal. This presentation is mediated by a computer-controlled random access slide projector and tape recorder which appears to have substantial motivating effects on students. Recently, a number of functions have been added to Coursewriter which do not require the student to exactly match an answer anticipated by the instructor. One of these functions permits partial answer processing of student answers. By means of these functions, the computer can be instructed to ignore trivial characters such as commas, periods, spaces, differences in word order, and misspelling if desired. A slightly more detailed description of the Coursewriter language is given in Chapter III.

The computer system employed in the investigation was an IBM 7010 (having compatibility with the IBM 1410), with remote IBM 1050 typewriter terminals. The main computer is located at the IBM Thomas J. Watson Research Center in Yorktown Heights, N. Y., while the typewriter terminals are located on the campus of The Pennsylvania State University. Transmission of information between the Penn State terminals and the central computer takes place over long distance telephone lines by means of teleprocessing. The instructional terminal (e.g., the IBM 1050) consists essentially of a modified IBM Selectric typewriter which permits two-way communication between a student at Penn State and the computer at Yorktown Heights. The terminal also contains a random access slide projector and tape recorder attachment. Course material can be presented to a student by typeouts, slides, or tape recordings. In answering a question or problem, the student types his answer at the terminal and relays it to the central computer. The computer then provides knowledge of results to the student, remedial information, or the next problem.

In addition to the student instruction mode, the typewriter terminal can also be used in "author mode" for input of course material, revision of course material, or for author testing of course material. The course input is transmitted to the computer where it is stored on high speed magnetic discs to which the computer has selective access to any part. In addition to "on-line" input of course materials, the use of a card punch attached to one of the typewriter terminals permits off-line course-writing on IBM cards. The cards can then be shipped to the central computer and transferred to disc or tape storage. This latter procedure frees more on-line terminal time for student instruction.

# CHAPTER III

## PREPARING COURSES FOR COMPUTER PRESENTATION

As aforementioned, courses have been prepared for presentation via Computer Assisted Instruction by means of a language known as Coursewriter. Although a complete description of the language is beyond the scope of this report, a summary of the functions of each of the operation codes is given below. A complete manual for the Coursewriter language is in preparation as an extension of the current Penn State program.

Summary of Coursewriter Operation Codes

rd - Computer types text and waits for the student to signal completion. Commonly used to display a reading assignment to a student.

qu - Computer types text and waits for student to respond. Commonly used to display questions or problems to a student.

ca - Correct answer to be stored in memory for comparison with a student's answer.

cb - Similar to ca, is used to identify one of a set of alternative correct answers when the subsequent action is the same regardless of which answer in the set is given by the student.

wa - Wrong answer to be compared with student's answer.

wb - Similar to wa, is used to identify one of a set of wrong answers when subsequent action is the same for all answers in the set.

un - Text to be typed if the student's answer is not one of the specified correct or wrong answers.

ty - Computer types text and continues without waiting for a response from the student.

br - Branch--alters the sequence of execution. Branches can be unconditional, i.g., not contingent upon a specific wrong or correct answer, or conditional upon the number of errors made by a student on a previous series of questions.

xl - Time limit--maximum number of seconds to wait for student to respond may be specified following this code.

ad - Add a quantity or the contents of a counter to a counter. Commonly used for accumulating a student's errors and response times. The contents of a counter may be tested by means of a conditional branch, and the course sequence altered depending on the contents of a student's counter.

nx - Instructs the computer "if not the preceding then do the following." It is used prior to each partial answer function and causes no interaction with the student.

fn - The fn statement is used to "call in" or activate a function.

fn slide//nnn - Used to present a slide; nnn represents the number of the slide to be displayed.

fn slide//nnnx - This function will seek and position slide nnn, but will not show the slide until a display slide function (see preceding function) occurs in the program.

fn dx// - This function will display the contents of an x-counter to the student specifying time.

fn wait// - This function allows the author to delay the program before continuing execution.

fn tape//nnn - This function will play tape recording number nnn.

fn tape//nnnx - This function will seek and position tape recording number nnn but will not play the recording until a tape play function (see preceding function) occurs in the program.

fn dc// - The display counter function is used to display the contents of a counter to the student.

fn lf// - The long feedback function is used to process student answers which are partially correct. The usual ca, cb, wa, and wb statements require an exact match with the student's answer. lf compares a student's answer with the subsequent ca or wa and identifies long segments of the answer which are matched. If the number of characters in the segments matched at least equals the per cent specified by the author, the function is satisfied and the matched portions are typed out with a "-" typed for each missing character still remaining. The function programed "fn lf//50" specifies a 50 per cent match.

fn mf// - The medium feedback function is essentially the same as the lf function except that it will recognize medium length segments; therefore, it is easier to satisfy than the lf.

fn sf// - The short feedback function is the same as the lf and mf functions except that it will recognize the shortest matched segments (individual characters); therefore, it is much easier to satisfy than the lf and mf.

fn lt, mt, and st refer to long test, medium test, and short test functions. They are analogous to the lf mf, and sf functions in providing partial answer processing of student answers; however, they do not provide the feedback of typing back "-" for missing characters.

fn kw// - The keyword function allows an author to specify one or more keywords which must be matched in the student's answer.

The above list of operation codes taken from the IBM Coursewriter manual (1965), although not exhaustive, covers most of the basic operations in the language. A reproduction of the course as it is stored in the computer is shown in Figure 1 (p. 13). Each operation code has an accompanying sequence number which is used to identify and sequence the course material. In preparing his program for the computer, the author prefaces segments of the course with the appropriate operation codes. The operation code indicates to the computer how the argument of that operation code is to be used. For example, the entry for a question consists of a qu followed by the text (argument) of the question. The qu code instructs the computer to type the question (argument) on the terminal and wait for the student to respond.

| Sequence No | Label | Opr Mode | Argument |
|---|---|---|---|
| aa-0010-010 | intro | qu | . . . . |
| aa-0010-020 | | ca | |
| aa-0010-030 | | ty | |
| aa-0010-040 | | wa | |
| aa-0010-050 | | ty | |

Fig. 1. Reproduction of CAI Course Segment

The amount of material stored at any given sequence number (referred to usually as a "line") is dependent upon the operation code used. There is no limit to the amount of material which can be stored in the argument of a rd, qu, ty, or un statement. If the statement is a ca, cb, wa, or wb, the argument is limited to 99 characters plus the EOB signal. Characters are letters, spaces, upshifts, downshifts, or any other single key operation on the typewriter terminal. The ca and wa used with either fn kw and fn lf, mf, sf, lt, mt, and st are limited to a few less characters.

The label is an identifying name for any statement in the course. The label provides a meaningful symbol which can be branched to by using a br statement.

One major objective of the present project was to test the feasibility of having regular college faculty members with minimal computer experience prepare courses for Computer Assisted Instruction. College level courses were prepared in four subject matter areas: audiology, modern mathematics, cost accounting, and engineering economics. Table 1 (p. 14) provides a summary of the course materials completed in the four course areas as of May 31, 1965. The values in this table are approximate, and include no indication of the number of statements[1] revised or rewritten.

TABLE 1

A Summary of Programed Materials Completed for Computer Assisted Instruction in Four Course Areas

| Course | Approximate number of statements in computer storage or ready for storage | Number of completed displays |
|---|---|---|
| Audiology | 3,900 | 12 |
| Cost Accounting | 7,000 | 30 |
| Modern Mathematics | 9,252 | 126 |
| Engineering Economics | 3,710 | 121 |

As can be seen in the sample of courses which follow, considerable variability exists in the programing strategies used by the different authors. This variability seems to be a function of differences in course content, the ease of programing different courses for the computer, and the authors' teaching preferences. For example, one of the authors is using primarily an inductive approach in which examples and problems are illustrated followed by questions designed to help the student discover the principle involved. Several authors employ a large number of branches to remedial or explanatory material, while others present explanatory material in the main trunk of their program. Some authors use a liberal number of prompts or hints to elicit student responses, while others require the student to do more independent searching for correct answers. Differences also exist in the kinds of questions that have been used (multiple choice, single word completion, true-false, multiple word constructed response) and in the quantity and quality of knowledge of results, feedback, and reinforcement. These "built in" differences among and within courses provide ready-made materials for future experimental tests of the effectiveness of the different methods of presentation.

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[1] A statement consists of an operation code and argument.

Our experience with programing different courses suggests that although most subject matters can be feasibly taught via CAI, some are especially well suited for computer-assisted instruction. For example, the presentation of visual and auditory materials via the slide projector and tape recorder would seem to be particularly effective where they provide nonredundant information to the learner. Simply presenting material on slides and tapes which can be presented as well by typeout to the student holds no great advantage for learning other than whatever advantages accrue from repeating the communication in the different sensory modalities. In many courses, however, information can be conveyed by the slides and tape recordings which could not be effectively transmitted to the learner by any other means. Although our experience to date has been primarily with visual displays printed in a workbook (the audio-visual tape and slide unit was only recently incorporated into the teaching system), this experience indicates that several of our courses are particularly well suited for the use of slides and tape recordings. For example, slides are being developed for the audiology course which portray various parts of the human auditory system. The slides are being developed in a manner similar to overlays emphasizing one section at a time until an entire anatomical system is displayed. Another particularly interesting use of the tape recorder is planned in the audiology course. Samples of pathological speech will be played for the students whose job it will be to learn to identify the different speech problems.

## Training CAI Course Authors

The present project was one of the first to implement the preparation of course materials for CAI using the Coursewriter language and teleprocessing from remote terminals. For this reason, problems were encountered early in the project which can now be avoided in future CAI projects. Although several short training workshops were held for the project staff by IBM personnel, it is fair to say that most of the project staff were to a great extent self-taught. Guidance was available to authors in the areas of learning and instruction; and as the project progressed, more experience was gained with CAI. Additional assistance became available to authors in the relatively unknown area of how to use the Coursewriter language to implement principles of instruction. It is hoped that our early experience with CAI will be of some help to other investigators who plan to do work in this area.

Although Coursewriter is a relatively simple language to use when compared to other more traditional programing languages such as Fortran, Daft, Algol, and Autocoder, a considerable amount of time was spent during the first few months of the project learning to use the language. In the judgment of the investigators, training authors in a more systematic fashion by means of a two- or three-week workshop to provide supervised coursewriting experience would be superior to the trial-and-error training necessitated in the present project. The training of authors in the early stages of the project was hampered by several problems: 1) the CAI hardware itself had only been recently installed and debugging was being completed; 2) the Coursewriter language was in the process of being written and revised, and thus, was constantly changing from week to week; 3) authors were faced with the more difficult problem of fully utilizing the instructional potential of CAI. It is anticipated that as more experience is gained with computer-assisted teaching systems, problems of author training will be minimized.

Aside from learning the Coursewriter operations, the most difficult problem facing a potential author of courses in CAI is that of utilizing the dynamic properties of CAI coursewriting. Preparing materials for CAI is very much different from one's experience preparing materials for a traditional lecture class of 40 or 50 students. Most traditional lectures, like earlier forms of programed instruction, involve essentially linear teaching strategies. To conceive of and develop a course which will adapt to the abilities and interests of any learner in a population of learners exhibiting typically wide individual differences requires skills which have frequently not been acquired by many teachers, nor have they often been taught in teacher training institutions. The most likely reason for the neglect of these skills for individualizing instruction is the great complexity which they introduce into the design of teaching strategies and instructional materials. Within the domain of adaptive CAI programing, one can conceive of multiple track and hierarchical instructional strategies which are difficult to visualize. A number of the authors have flow charted their courses prior to the actual production of the course. Flow charting has the advantage of forcing an author to state his objectives prior to course development, and to draw out various routes through the course by which students of different abilities and interests can reach these objectives.

The use of adaptive CAI programing also involves some assumptions about the nature of student learning which are frequently either unaccepted or ignored in traditional teaching situations. The use of adaptive teaching systems such as Computer Assisted Instruction assumes the variability in attainment of learning objectives among different learners can be substantially reduced. Although some psychologists find evidence for a genetic limit in a student's learning ability, recent evidence points to the great malleability of such variables as measured intelligence and school learning. One of the most striking early findings of the present investigation (more fully reported in Chapter IV, p. 73) was the great spread of criterion test performance among college students on CAI courses specifically designed to include remedial work and adaptation to individual differences. In one section of modern mathematics containing approximately 50 per cent remedial work given to students having difficulty in the main course, criterion achievement test scores ranged from 5 to 23 on a 23 item test. The reader should note that these were a select sample of college students having generally high mean academic aptitude test scores and low range. That such widespread variability in learning was found among such students can only stem from a failure of the instructional strategy. One of the most valuable attributes of Computer Assisted Instruction for training instructional programers is the ease with which authors obtain feedback concerning the adequacy of their courses. In the normal classroom situation, feedback concerning one's teaching procedures is frequently delayed too long for the feedback to be relevant. In CAI, feedback concerning one's course can be obtained almost immediately by signing on as an author-student to test the course. Rarely does the classroom teacher have an opportunity to "sit in the student's shoes"; however, such experience is the rule rather than the exception in CAI. In addition to having firsthand experience as a student on one's own course, information concerning the performance of regular students is readily available. Such students have been used to provide information concerning "debugging" of courses, and to help diagnose the strengths and weaknesses of a course.

Capabilities for rapid revision are required of an instructional system if feedback concerning the adequacy of instruction is to lead to improvements in the course. One of the major advantages of CAI is its potential for rapid revision of course materials. Depending on previous scheduling of computer time, minor revisions can often be made the same day, while more extensive revisions can be made within several days. This is a particularly important characteristic since the preparation of course material frequently requires considerable revision to smooth out minor defects.

Most of the "bugs" encountered in the present project can be attributable to author errors in programing and to the author's inexperience with CAI. Preliminary results concerning the incidence of mechanical malfunctions have been highly encouraging especially in view of the complex electronic system involved. One objective of the project was to test the feasibility of teleprocessing course material to remote instructional terminals. A check of a sample of 10,374 statements of program completed by a small sample of students showed that transmission errors occurred in only 0.2 per cent of the statements. On the basis of these preliminary results, we can conclude with some certainty that Computer Assisted Instruction at remote terminals via teleprocessing is surprisingly free of mechanical malfunctions.

One of the major results of the project was the development of four workable CAI courses. Although some of our course materials are still in need of "debugging" and student testing, it is fair to say that these "first drafts" form the basis of satisfactory CAI course materials. Some sections of the courses have been tested with students, and preliminary evidence reported in Chapter IV (p. 73) indicates that the students generally reacted favorably to them. Owing to the length of the courses [see Table 1 (p. 14)], reproduction of the entire four courses is beyond the scope of this report. However, one section of each course is presented here in the form of coded author input to provide some indication of the kinds of materials being prepared. Following the author materials, a short section of student typeout (i.e., course material encountered by the student in taking the course) is presented. In the courses which follow, slide, tape or other display materials are presented between the solid lines where they would actually occur. Occassional explanations of coding are also presented between the solid lines.

Preceding each sample of course material, the authors have prepared a brief statement describing the course, the results of any preliminary evaluations they may have completed, and problems they encountered during course preparation. These statements are presented to provide future CAI course authors with the benefits of the reactions of our authors.

## Introduction to Audiology

Prepared by:

Bruce M. Siegenthaler and Jeffrey Katzer

Speech Pathology and Audiology 430 is our first course in audiology. It has the title "Introduction to Audiology" (3 credits) and normally is taken during a student's junior year of undergraduate study.

The objectives of this course include the following:

1. Introductory survey of the field of audiology
2. Development of a knowledge of technical terms used in audiology
3. Classification of information regarding the anatomy and physiology of the normal ear and of ear diseases at a survey level
4. Understanding of general principles of hearing testing and development of skill in administering pure tone air conduction tests and their interpretation
5. Survey of rehabilitation measures for hearing handicapped

Although the course is required during the junior year of the undergraduate SPA curriculum, and the major enrollment is by students so enrolled, the course is also taken by a number of graduate students in the master's program in SPA, and by students from outside SPA who minor in this field.

During the Winter Term 1965 we completed a small-scale evaluation of CAI as applied to SPA 430. Of the approximately 25 students enrolled in the class, 12 volunteered to participate in CAI as supplementary to class attendance. These 12 volunteers were divided by a random process into two groups, one to receive CAI and the other not. All students enrolled in the course attended the three lectures per week. However, the six selected students spent time on the computer terminal to complete the amount of material on anatomy and physiology of the ear then programed. At the end of the first third of the course (when the work on anatomy and physiology was completed), all students received the comprehensive test on that material. The test response papers allowed us to analyze test scores of students who had not volunteered for CAI, of students who volunteered for CAI but who were not selected, and for students who volunteered and were selected. Furthermore, for the CAI selected students, we were able to compare their scores upon those questions supplemented by CAI and those questions not supplemented by CAI.

The results, based upon a very small sample as cited above, did not indicate a clear-cut advantage for the students receiving CAI either for the CAI related questions or for the non-CAI related questions. However, it must be remembered that all students attended all lecture sessions and therefore all received the same instruction via lectures.

Students' subjective evaluations of the computer program were highly enthusiastic. Some of them were able to complete all of the program material in as little as two hours on the terminal, while others required about six hours. Those who were on the terminals commented that they felt they had benefited by the instruction (although their scores did not clearly indicate this), and all of them expressed a high level of interest and motivation to continue with additional CAI activities.

Thus far the advantages of CAI for SPA 430 are only based upon subjective evaluations or upon projections of what we would like to do. Specifically, apparently the technique holds promise for significantly shortening the amount of time a student will have to spend per week on the course content. Students should be able to move through the material at their individual learning rates with as little or as much time as each student needs to complete the material. We feel that a modification of the terminal ought to simulate the audiometric test situation in a realistic manner which would allow us to give students considerable practice helpful in pure tone test administration to an extent not now possible with our present facilities.

Sample Program

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| | qu | This is Computer Assisted Instruction (CAI) for the Penn State course Speech Pathology and Audiology 430: Introduction to Audiology. SPA 430 will be taught by individual work at this terminal and by classroom instruction. There will be one classroom period per week. It is the student's responsibility to obtain the required instruction after each classroom period at this terminal before the following class period.<br>The text for this course is Audiology (2nd edition) by Hayes A. Newby. As we shall be referring to it often, bring the text with you to all CAI sessions, as well as to the class period.<br>You may find the CAI terminal procedure a bit complex during your first week's instruction. However, students rapidly become the master of the situation. If, during your instruction, either the terminal equipment or the course material is not functioning properly, notify the secretary for information or materials you will need during your CAI sessions.<br>There are several ways in which material will be presented to you. To find out one of them, type:<br>slide<br>Do not forget to press the necessary: EOB afterward |

```
LABEL   OPR MODE   ARGUMENT
             ca    slide
             nx
             fn    kw//2
             ca    ,s,lide
             un    Read the last sentence of the preceding material and
                   type the word:     slide     then press:     EOB
```

*This material is simply an introduction to the audiology course. The coding immediately above illustrates the keyboard function (e.g., fn kw//2). The computer compares the student's response with the ca "slide," and if a match is obtained, it goes to the next* <u>*rd*</u>*. If an exact match is not obtained, the computer searches the student's response for the single keyword "slide," which if found, will cause the computer to proceed to the next* <u>*rd*</u>*. In this instance the keyword function enables the student to capitalize "slide" or put in punctuation such as a period without getting an incorrect response from the computer. If the word "slide" is not found in the student's response, the material under the* <u>*un*</u> *(unanticipated answer) is typed out to the student. The instruction to "press EOB" is a simple operation used by the student to transmit his response to the computer.**

```
             rd
             fn    slide//001
```

<u>Contents of slide 001</u>:

Sometimes you may have material presented on a slide. It may be text, or more frequently, it will be a drawing or picture. Often the slides will be correlated with a hand-out that you will write or draw upon as instructed.

When you have finished reading this slide, press:     EOB

---

*N.B. All material in italics represents author's explanatory comments about the stored computer program.

```
LABEL   OPR MODE   ARGUMENT
           rd      Read the material on the slide.  When you have finished,
                   press:    EOB
           fn      slide//2x
           qu      There is another way that you will be presented
                   material on some occasions.  To find out what it is,
                   type:   tape
                   and press:    EOB
           ca      tape
           nx
           fn      kw//1
           ca      ,tape
           un      Reread the preceding information and type the word:
                   tape
                   followed by an:    EOB
tapel      rd
           fn      tape//001
```

---

<u>Contents of tape</u> 001:

A tape play-back is part of this system. The tape may be used to help you with the pronunciation of the technical terms. Other times you will be given visual materials, such as a slide, and the tape will direct your attention to certain parts of a displayed slide.

---

```
           fn      tape//002x
           qu      If you would like to hear the tape again, type:
                   repeat tape
                   followed by the standard:    EOB
                   If you would rather go on, type:    go on
           ca      repeat tape
           nx
           fn      kw//1
           ca      ,repeat tape
           br      tapel
           ca      go on
           un      Reread the directions and type:    repeat tape
                   or:    go on
```

*The prior sequence illustrates a looping type branch designed to allow the student the option of repeating the tape. If the student chooses to type "repeat tape" the branch, br tape1 will be enacted sending the student back to the label, (tape1) shown previously. If the student chooses to go on, he circumvents the branch and is sent on to the next rd. Again the un is included to take care of the possibility of an unanticipated answer.*

```
rd
fn      slide//002
fn      tape//002
```

---

Contents of slide 002 and tape 002:

Now read along on the slide with me. Throughout your CAI work you will be asked many questions and you will respond by typing the answers on the CAI typewriter. Sometimes there will be one question followed by or preceded by some instructional material. Other times you will have a whole series of questions, which will look a lot like a test--but won't be. This CAI program is being used solely for teaching. All testing, for purposes of grades, will take place in regular classroom sessions.

---

```
fn      tape//003x
rd      Now we are ready to get into some of the substantive
        material of the course.
        Read pages 16-18 in Newby.  Press:     EOB
        when this reading is completed.
br      1-1
```

*The coding above illustrates the sequence commonly used to display a series of slides or tape recordings to student. The blank rd is used much like the title of a list which marks out a series of slide and tape operations. In this case slide 002 will be shown followed immediately by tape 002. After playing tape 002, the computer will seek and position tape 003.*

```
LABEL   OPR MODE   ARGUMENT
 1-1       qu      1-1.  Following the normal pathway of sound, what are
                   the three main divisions of the ear?
           ca      outer ear, middle ear, inner ear
           ty      Correct.  Let us look at the outer ear first.
           nx
           fn      kw//3x
           ca      ,,outer,,middle,,inner
           nx
           fn      kw//3x
           ca      ,,external,,middle,,inner
           un      Incorrect.  You should refer back to Newby pages 16-18
                   and try again.
```

*The above sequence illustrates a more practical example of the keyword function. Prior to the development of the keyword function, the above question contained 40 alternative correct answers to anticipate all the ways a student might write outer ear, middle ear, inner ear, or external ear, etc. The variations in student correct responses can now be anticipated with two keyword functions.*

```
           qu      1-2.  What is another name for the outer ear?
           ca      external ear
           ty      Correct--that is, the first division of the ear is the
                   outer or external ear.
           wa      external
           ty      External what?  Try again and use the complete name.
           wa      pinna
           wb      external canal
           wb      auricle
           wb      external meatus
           wb      external acoustic meatus
           ty      You are giving only a part of the outer ear.  The
                   desired alternative name includes all of the outer
                   ear.  Try again.
```

*The prior sequence illustrates the use of a wa-wb wrong answer sequence. The course author may anticipate any number of wrong answers or partially right answers, and provide additional clues to the student as was done in the above typeout ty.*

```
nx
fn      kw//2
ca      ,external,ear
un      The correct answer is external ear.  Type it in.
qu      1-3.  What is the name for that part of the external
        ear most visible and on the outside of the head?
ca      pinna
ty      Correct.  Remember that another name for the pinna is
        auricle.
br      0-11
ca      auricle
ty      Correct.  Remember that another name for the auricle
        is pinna.
br      0-11
ca      pinna or auricle
cb      auricle or pinna
ty      Correct.  These are two names for the same thing.
br      0-11
wa      lobe
wb      ear lobe
wb      earlobe
wb      lobule
ty      The ear lobe (two words) or lobule is on a small part
        of the desired structure.  Try again.
nx
fn      sf//50
wa      pinna or auricle
un      You are less than 50% correct.  Let's try a different
        approach.
```

```
LABEL   OPR MODE   ARGUMENT
           br      0-10
 0-10      qu      What is the term used in Newby's Fig. 2-2 on page 16
                   for the externally most visible part?
           ca      auricle
           ty      Correct.  Remember that another name for the auricle
                   is the pinna.
           wa      external canal
           wb      outer ear
           wb      mastoid cells
           ty      Reread the last question and try again.
           nx
           fn      kw//1
           ca      ,auricle
           un      The correct answer is the bottom label on the left
                   side of the diagram.  Type this correct answer.
 0-11      qu      1-4.  What small structure of the ear divides the
                   external ear from the middle ear?  (You need a
                   SPECULUM to see it.)
           ca      tympanic membrane
           ty      The tympanic membrane (abbreviated T.M. or t.m.) is
                   the term we will be using.  Less technical, but
                   respectable names are "eardrum," "drum membrane," and
                   "eardrum membrane."
           wa      eardrum
           wb      drum membrane
           wb      eardrum membrane
           wb      ear drum
           wb      ear drum membrane
           ty      This is correct; however, a more technical name that
                   we shall be using is TYMPANIC MEMBRANE (abbreviated
                   T.M. or t.m.).  Please type:     tympanic membrane.
           nx
           fn      sf//50
           wa      tympanic membrane
           un      You are less than 50% correct.  What is the first
                   structure that sound waves encounter as they pass
                   inward beyond the pinna?
```

| LABEL | OPR | MODE | ARGUMENT |
|---|---|---|---|
| | | un | Following Newby's diagram on page 16, what is the first normal structure that you would encounter? |

> *The audiology course employs some interesting displays used by the student at the terminal. In addition to pictures and diagrams of the ear the student works with plastic models of various parts of the ear, and a human skull. A large number of slides are going to be prepared to help the student visualize the numerous parts of the auditory system.*

## Modern Mathematics

Prepared by:

C. Alan Riedesel and Marilyn Suydam

### Theoretical Premises

The strategy of instruction for the CAI Modern Mathematics program uses several basic assumptions concerning the teaching-learning process. These are

1. Mathematics is best learned when students are encouraged to discover the basic ideas, laws, or principles of mathematics. Thus, students should be given a chance to solve a new problem rather than be first "shown" how to solve a problem.
2. The reason for studying a topic should be made clear by the manner in which it is introduced.
3. Individuals vary in their receptivity for learning.
4. Effective learning is continuous and developmental in nature; thus, previous generalizations and facts are helpful in developing new generalizations.
5. Continual failure by an individual makes for ineffective learning.
6. Active participation by the student tends to produce an effective learning experience.
7. Knowledge of one's progress contributes to effective learning.

A belief in these assumptions leads to a teaching procedure in which the student is presented with a problem that can be solved by his use of previous knowledge and his thoughtful discovery of the next step of knowledge in the subject. This approach can be called an inductive approach. A deductive approach is usually used in programed materials. The following diagram contrasts these two approaches to teaching mathematics.

| Inductive Approach | | Deductive Approach |
|---|---|---|
| Student is presented with a problem. | | Student is presented with generalization. |
| If problem is solved by student, he is led to refine his procedure for solving problems of this type. | If student cannot solve problem, he is asked developmental questions which lead to the solution. Student solves similar problem. | Student is quizzed concerning aspects of the generalization. |
| Student is asked to develop a generalization. | | Student is presented with illustrative problems in which the process of solution is explained to him. |
| Student is quizzed concerning aspects of the generalization. | | Student applies the generalization to solving problems. |

The Modern Mathematics program attempts to make use of a teaching technique similar to the inductive pattern. An illustration of such a pattern for classroom use is as follows:

Purpose of the lesson: To develop an understanding of the use of the inverse (reciprocal) in dividing rational numbers.

The teacher stated: "We've been solving division problems involving the use of rational numbers in several ways. Now let us see if we can find a more efficient method of solution. What are various ways in which we can write 6 ÷ 3/4?"

The following ways were suggested by the students:

| (a) | (b) | (c) |
|---|---|---|
| $6 \div 3/4 = N$ | $\frac{6}{\frac{3}{4}} = n$ | $\frac{3}{4}\,\overline{)\,6\;}$ |

The teacher said: "Look at Form (b) $\frac{6}{\frac{3}{4}}$. If we could reduce this fraction, we could solve the problem. What would be the denominator that would make reduction of the fraction simplest to perform?

Pupils suggested that the easiest fraction to reduce would be a fraction with a denominator of 1. The teacher asked: "How could we change the denominator from 3/4 to 1?"

Students recalled that by multiplying by the inverse--the reciprocal of 3/4, which is 4/3--the denominator would be 1. Pupils then said that if the denominator was multiplied by 4/3, the numerator would also have to be multiplied by 4/3 (an application of the role of the identity element for multiplication which is 1. $\frac{\frac{4}{3}}{\frac{4}{3}}$ is another name for 1).

The resultant problem was written on the chalkboard in the following form:

$$\frac{6 \times \frac{4}{3}}{\frac{3}{4} \times \frac{4}{3}}$$

Students continued to work division problems in this manner for a time. When the teacher felt that the students had a good understanding of this approach, discussion and guided questions were used to develop the idea that it is not actually necessary to write all of the material--actually, inverting the divisor accomplishes the desired result. Thus

$$5 \div \frac{1}{2} = 5 \times \frac{2}{1} = 10$$

$$\frac{5 \times \frac{2}{1}}{\frac{1}{2} \times \frac{2}{1}}$$

A teacher using a deductive format for the teaching of inversion would have first explained the approach to the class and then had the students practice its use.

Certain problems have arisen in the course of applying this theory to the writing of the program in modern mathematics. Initially, to transfer a concept of an ideal situation to a programing mode is difficult because of dealing with an imaginary student. It is especially hard to anticipate student answers; the possibilities seem infinite at times. There is the tendency, therefore, to write a linear pattern with many multiple-choice items. The linear pattern assures us that everyone will see the (sometimes) clever things we've written. The multiple-choice item limits the student's choice and therefore the difficulty of having to deal with the unanticipated when, by definition, we can't anticipate it! Partial answer processing functions have helped with this problem to some extent.

Another difficulty in a course designed primarily for future teachers is *finding real life situations* which make sense to adults and also which can be applicable at an elementary level is apparent. The transfer to a real elementary classroom situation is essential; hopefully the method by which the material is taught to teachers will affect their own teaching procedures.

Some difficulty has been met in *determining "size of steps"*--asking the questions which lead from one point to the next. This has involved a value judgment, and we find that step size varies with type of material.

An even larger problem has been that of attempting to *determine the patterns of learning* for various students--taking into account individual differences. The amount of practice and remedial material, the type of vocabulary, the type of learning structure--in short, the *needs* of individual students must be taken into account. Some branching opportunities are provided on the basis of each of these variables and more should be added as we analyze student records.

*Traditional materials provided little real help* except in terms of basic content since they operate from a different framework. Meaningful problem situations are generally lacking in them; deductive, rule-stating approaches are generally used; there is a heavy emphasis on vocabulary rather than on concept-formation. We have visualized a good teaching-learning situation, on the other hand, and have tried to lead the student to discover concepts and broader principles.

We feel *hampered by the lack of ability to allow a student to be "creative"*--he must conform to our expectation of what answers are probable, possible, and acceptable. There is definitely a need for additional contacts with a teacher and/or other discussion situations to allow questioning, even more inductive problem-solving, and creative thinking. Structuring the program through an "inquiry" or "discovery" approach seems vital to counteract, in part, this handicap.

## Scope and Sequence

The Modmath Program provides the background for understanding mathematical *content* and *concepts* of the system of real numbers and its component systems, including basic set theory, varying numeration systems, operations, properties, and algorithms. The program is developed with reference to teaching in the elementary school.

The breadth of the program proved to be a limitation--this is a great deal of material to program. The pressure produced by volume was compounded by time--the need to complete a first draft of the entire program within the specified number of months. Because of this pressure, much more of a Skinnerian or linear program (with comparatively few branches) resulted, and the potential of CAI was not fully utilized.

The writing is not as creative as it might be; it takes a vast amount of time to develop original approaches. Complete utilization of available functions has not been possible. In addition, the increase of available functions has changed the possible format of the program; we have found it impossible to keep each segment rewritten in terms of new formats subsequently issued; as a result, the treatment of material in some chapters is far more precise than in others. For example, the first chapters were written before partial answer processing of answers was possible; therefore, the number of short answers, requiring exact matching, is greater than in later chapters.

While the details of our procedural steps for each chapter differed, they might be roughly or approximately outlined as follows:

1. Develop outline with the amount of detail differing with the topic. Use was made of two basic sources--Theory of Arithmetic, by Peterson and Hashisaki, and Arithmetic and Its Structure and Principles, by Mueller--and many additional supplementary references.
2. Delineate principal questions, which lead to development of the content in the outline.
3. Complete the writing, using Coursewriter instructions, branching to meet individual needs and so on.
4. Reread, then rewrite; reread, then rewrite--generally two or three repetitions of this are involved at this stage. Discussion between the authors was important here as at other stages.
5. Have program typed; reread for accuracy and make any changes apparently necessary.
6. After the program is in the computer, at least one rereading is necessary, reading for errors in input and any other errors that are apparent; then rewrite.

7. After students have worked through a section, more revision is done in terms of their comments and answers, which are analyzed and evaluated. (Continuous evaluation and rewriting is, obviously, necessary!)

The Coursewriter which is being developed by IBM should prove very useful: the difficulty that we have found is that it is being written as we go along. The continual change of functions, and in particular the addition of functions, implied virtually continual rewriting. We felt negligent for not using all of them, even in material that was being written concurrent to their appearance. Yet we couldn't possibly keep the program in all ways up to date and still complete the total first draft.

The material which seems to be in the computer is not always what is actually there: the typewriter keyboard may be handled in various ways. For instance, 3 + 4 = 7 may look just like 3 + 4 = 7. But in the first case, the shift was touched right after the 3; in the second case, a space was typed before the upshift. Transfer this case to the computer: the student types what he knows is correct, but is continually told he is wrong--and moreover, is told to type just what he has been typing 3 + 4 = 7! Because the correct answer which the machine will accept has been typed in a different form, he cannot match it or he wastes time trying to. Gradually, this type of problem is being eliminated through adding various typing patterns in providing correct answers and through partial answer processing.

Because of brief system failure and other reasons, such as the conversion from one computer system to another, some input data has been "lost" or else appears incorrectly in the type-out. This necessitates additional rewriting and/or reinsertion.

Further planning includes revision of the existing program after evaluation of student records; this is a continuous process. We realize that more review and practice should be included, and tests for all chapters must be devised. We anticipate using student records to aid in these developments. We will, of course, include the audio-visual functions which have become available, as well as include the more recent partial answer functions throughout the program.

We are also considering the development of parallel programs which utilize the variables of individual differences more effectively. Through pretesting, determination of the type of program to which a student should be branched may be possible, and within-track and inter-track branching will be utilized.

In short, we completed the first stage! We have developed a program which we feel is sound; with revision improvements, it should develop into a program which will serve its purpose well.

Sample Program

```
LABEL    OPR MODE    ARGUMENT
 5-1        qu       Let's begin with a quick review of a few basics about
                     the number system we commonly use, base ten.
                     How many single digits are there in base ten?
            ca       10
            cb       10 (lower case el)
            cb       ten
            ty       Correct
            un       Think for a minute--5 is a digit; 0 is a digit;
                     How many single digits are there?  (Remember to type 1
                     and not el.)
            ad       -1//c1
            un       There are 10 digits.  Type 10.
            ad       -1//c1
```

*The above sequencing illustrates a fairly typical frame in Chapter 5 of Modern Mathematics designed to teach number systems with bases other than ten. Notice that alternative correct answers are anticipated by a ca - cb-sequence. If the computer matches the student's response with any one of the three correct answers, it types the text of the ty which in this case tells the student that he is correct, and then goes directly to the next question. If a correct answer match is not obtained in this frame, the text of the first un will be typed to the student. A most important operation in the above segment is the ad statement. After each occurrence of a un (in this case, a wrong answer) the computer adds -1 to counter 1, thus accumulating the student's* *errors. A little later in the course, the coding calls for the computer to test the contents of counter 1 and branches the student to remedial work based on the total number of errors in the counter.*

```
5-2       qu     You noted that the single digits in base ten include
                 0,1,2,3,4,5,6,7,8,9.  In base 10, what number
                 designates one more than 9?
          ca     10
          cb     ten
          ty     Correct
          un     Confused?  The answer is 10.  Type 10.
          ad     -1//cl
5-3       qu     This is the beginning of the concept of place value.
                 The 1 in 10 now means not a single one, but--right!
                 one group of ten!  What does the 3 in 30 mean?
          ca     3 tens
          cb     three tens
          cb     three groups of ten
          cb     3 groups of ten
          ty     Correct
          un     We write this out as "3 tens" or "three tens."
                 Type one of these forms.
          ad     -1//cl
5-4       qu     And in 74, which numeral designates the number of tens?
          ca     7
          cb     seven
          ty     Correct
          un     The number 4 is in the ones place.  What number is in
                 the tens place?
          ad     -1//cl
5-5       qu     When we add 1 to 99, we have 9 tens and 10 ones.  The
                 10 ones form 1 ten, so we have 10 tens.  How do we
                 write "10 tens" with numerals?
          ca     100
          ty     Correct
```

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| | un | What number comes after 99? Type it in digits. |
| | ad | -1//cl |
| 5-6 | qu | The 1 is now in the hundreds place. With what number do we first use the thousands place? |
| | ca | 1000 |
| | cb | one thousand |
| | ty | Correct |
| | un | Think of the largest 3-place number--right! 999 Now add 1 to this, & type your answer. |
| | ad | -1//cl |
| 5-7 | qu | Look at Display 5-A. Notice the relationship involved in the place value system of base ten. Since we cannot at this point write exponents on the machine, we will write its meaning in words. 1 = ten to the zero power, 10 = ten to the first power, 100 = ten to the second power, or ten squared. What is 1000 expressed as a power of 10? |

Display 5-A

| $10^5$ | $10^4$ | $10^3$ | $10^2$ | $10^1$ | $10^0$ |
|---|---|---|---|---|---|
| ten to the fifth power | ten to the fourth power | ten to the third power or ten cubed | ten to the second power or ten squared | ten to the first power | ten to the zero power |
| 10x10x10x10x10 | 10x10x10x10 | 10x10x10 | 10x10 | 10 | 1 |
| 100,000's | 10,000's | 1,000's | 100's | 10's | 1's |
| hundred-thousands | ten-thousands | thousands | hundreds | tens | units or ones |
| base x base x base x base x base | base x base x base x base | base x base x base | base x base | base | |

This chart shows the place value system of base ten. Thus $10^2$ (or 10 squared) means the 100's, or hundreds, or base x base column. The basic outline can be used in terms of any base.

```
LABEL   OPR MODE   ARGUMENT
            ca     cubed
            cb     10 to the third power
            cb     10 exp 3
            cb     10 (exp) 3
            cb     ten cubed
            cb     ten to the third power
            cb     10 to the 3rd power
            ty     Correct
            un     Notice the order of the exponents (0,1,2).  Therefore,
                   what would come after 10 squared or 10 to the second
                   power?
            ad     -1//c1
            un     The correct answer is "10 to the third power"  Type
                   this.
            ad     -1//c1
 5-8        qu     How would the next place be expressed in terms of
                   exponents?
            ca     10 to the fourth power
            cb     ten to the fourth power
            cb     10 to the 4th power
            cb     10 exp 4
            cb     10 (exp) 4
            ty     Correct
            un     A new place is reached with 10,000.  This is 10x10x10x10.
                   Written in exponential form, this is "10 to the ______
                   power."
            ad     -1//c1
            un     Type "10 to the fourth power."
            ad     -1//c1
            rd
            br     rem1//c1//4
            br     5-9
rem1        rd     You could profit from some review of our numeration
                   system.  Read Mueller, Chapter 3.  Then press EOB.
```

*The above segment illustrates several interesting features of Coursewriter. You will recall that after each incorrect answer the computer added -1 to counter 1. The above code written br reml//cl//4 is an example of a conditional branch. The statement is read, branch to the first argument (reml) if the value of the second argument (contents of counter 1) plus the amount of the third argument (4) is zero or negative. Thus, the author has decided that if the student has made four or more errors in the first eight questions, he should be branched to remedial work. The remedial work in this example consists of the direction to read certain text materials given in the following rd statement. Another important point to note in the above sequencing is that the student who has not committed the required four errors is branched around the remedial work by the code br 5-9. This segment illustrates the power of Coursewriter for individualizing instruction.*

5-9 rd Now let's proceed. Read Display 5-B. When finished (EOB).

---

Display 5-B

One of the best ways to gain insight into the structure of our base ten system is to consider a system that has the same basic pattern as ours, but employs a different number for its base or radix. There are other reasons for such a study: (1) The problems encountered are somewhat similar to those encountered by a child learning the base ten system, (though it should be noted that they may be different because of the unlearning you will have to do); (2) The electronic computers of today use a base of two to perform their operations; (3) Proposals are often made to change our base from 10 to 12 or to 18; and (4) Such a study is usually interesting for its own sake.

While the exact reasons for the development of our number system based on ten is unknown, its most probable origin is not difficult to note. What does a child use as he learns to count? Most probably, his fingers. With this aid to counting ever present, it provided a logical basis as a number system evolved.

Of course, at various times different groups of people have used systems based on numbers other than ten. There were isolated tribes born with six fingers on a hand--the use of base 6 or 12 was indicated.

Some groups used the fingers of only one hand and developed a system based on 5. The Mayans of Yucatan are only one of several peoples who used a number base of 20--possibly originating from the counting of toes as well as fingers.

But now let's return to base ten for a few questions.

Bibliography for the chapter:

Mueller, Francis, *Arithmetic Its Structure and Concepts*, Chapter 1, Unit 4.

Peterson and Hashisaki, *Theory of Arithmetic*, Chapter 4.

Spooner, George, *Mathematics Enrichment*, Program A, B, and C.

---

| | | |
|---|---|---|
| 5-10 | qu | Suppose a group of persons in an isolated location were all born with four fingers on each hand. What number base would these persons (with four fingers on each hand) probably have used? |
| | ca | 8 |
| | cb | eight |
| | cb | base 8 |
| | cb | base eight |
| | ty | Correct |
| | un | Think it through more carefully: how many fingers do we have in all? What base do we use? What base would an eight fingered person probably use? Now type your answer. |
| | un | The answer is 8. Type 8. |
| 5-11 | qu | Remember that base ten has ten single digits. But how many will base eight have? |
| | ca | 8 |
| | cb | eight |
| | ty | Correct |
| | un | Base *eight* has *eight* single digits. Type eight. |
| 5-12 | qu | Let's try counting in base eight: 1,2,3,4,5,6,7-- and we need a digit to represent the empty set--0. That's eight digits. If we add 1 more, we reach 8-- but 8 is not a digit in base eight. Recall what happens under the same circumstances in base ten; |

| | | |
|---|---|---|
| | | now write the numeral which means "one of the base and zero ones," in base eight. |
| | ca | 10 (eight) |
| | cb | 10 (eight) (lower case el) |
| | ty | Correct |
| | ca | 10 |
| | ty | 10 (eight) is more definitive. In order to clarify whether we are working with base ten numerals or base eight numerals, all base numerals will be written in the following fashion: 5 (eight), meaning "5 in base eight." Remember to use this form. |
| | un | The number after 7 in base eight is 10 (eight), which means "one group of the base (eight) and zero ones." Type 10 (eight). |
| 5-13 | rd | Turn to Display 5-C. When you have finished reading, press (EOB). |
| 5-14 | qu | Now study the number line in Display 5-D. What number should appear after 17 (eight)? |

---

Display 5-C

It has been noted that in this program on the machine, because of typing limitations we use parentheses after a numeral to designate the base, as in 3 (eight). You should be aware that there are other ways of writing the base notation, used in non-machine material. Among these are $3_8$ and $3_{eight}$. Among mathematicians there is some objection to the use of the numeral 8 to indicate the base: they say that there is no such numeral in the base. However, this is argumentative, since it is the name for the base and distinguishes the base as well as the word eight.

Display 5-D

(1)

Base ten 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

Base eight 0 1 2 3 4 5 6 7 10 11 12 13 14 15 16 17 ? ? ? ? ?

(2)

x x x x x

x x x x x

x x x x x

x x x x x

x x x x x

EXAMPLE
BASE EIGHT

```
X X X X
X X X X
       X X X = 23 (eight) =
X X X X        2 of the base and
X X X X        3 units
```

---

| | | |
|---|---|---|
| | ca | 20 (eight) |
| | ty | Correct |
| | ca | 20 |
| | ty | Correct - Remember it is 20 in base eight. |
| | wa | 18 |
| | wb | 18 (eight) |
| | ty | Do we use the numeral 8 in base eight? One of the base and 8 more would equal 2 of the base. How should 2 of the base be written? |
| | un | The numeral after 17 (eight) would represent 2 of the base. How should 2 of the base be written? |
| | un | The number after 17 (eight) would be 2 of the base or 20 (eight). Type 20 (eight) |
| 5-15 | qu | What numeral will follow 20 (eight)? |
| | ca | 21 (eight) |
| | ty | Correct |
| | ca | 21 |
| | ty | Correct--21 in base eight. |
| | un | The correct answer is 21 (eight), meaning "two of the base and one more." Type the correct answer. |
| 5-16 | qu | Look at exercise 2 in Display 5-D. Circle the x's into groups of eight. How many groups of eight are there? |

```
LABEL     OPR MODE   ARGUMENT
             ca      3
             cb      three
             cb      three (eight)
             cb      3 (eight)
             ty      Correct
             br      5-17
             un      Incorrect
             br      5-16-1
5-16-1       qu      If you were counting the x's in base 10, how many x's
                     would there be in all?
             ca      25 (ten)
             cb      25
             un      The correct answer is 25 (ten).  Type it.
5-16-2       qu      How many 8's are in 25 (ten)?
             ca      3
             cb      three
             un      There are three 8's in 25 (ten).  Type 3.
```

*The above segment illustrates another short remedial branch. An incorrect response to question 5-16 branches the student to remedial question 5-16-1, whereas a correct response branches the student around the remedial work to question 5-17. The system of labels used in the modern mathematics course indicates the chapter by the first numeral, the number of the main trunk question by the second numeral, and successive remedial questions by the third numeral.*

```
5-17         qu      How many ones are left over?
             ca      1
             cb      one
             un      The correct answer is 1 or one.  Type it.
5-18         qu      How would you represent the number in base eight
                     associated with the x's?
             ca      31 (eight)
             ty      Correct
```

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| | ca | 31 |
| | ty | Correct--31 in base eight. |
| | un | How many groups of the base (eights) are contained in the x's? How many ones? Try again. |
| | un | There are 3 groups of the base (eight) and 1 one. Type 31 (eight). |
| 5-19 | qu | Write the numeral in base eight which means "five eights and seven ones." |
| | ca | 57 (eight) |
| | cb | 57 |
| | ty | Correct |
| | un | The correct answer should be 57 (eight). |
| 5-20 | qu | Recall the progression of place values in base ten. (If you need review, check Display 5-A.) In base eight, place values are of course based on powers of eight. Turn to Display 5-E, and study the place value chart. What numeral should be inserted in place of A? |
| | ca | 64 |
| | ty | Correct |
| | un | The correct answer should be 64. Type it. |
| 5-21 | qu | After 8 x 8 would come 8 x 8 x 8. What numeral should be inserted in place of B? |
| | ca | 512 |
| | ty | Right! |
| | un | 8 x 8 x 8 or 8 cubed = 512. Type 512. |
| 5-22 | qu | When working with other bases, we frequently change a number from one base to another. What is the value of 37 (ten) in base eight? |
| | ca | 45 (eight) |
| | ty | Correct |
| | br | 5-23 |
| | ca | 45 |
| | ty | Correct, 37 (ten) = 45 (eight) |
| | br | 5-23 |

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| | un | Incorrect. Let's break the problem down into smaller steps. If, however, you realize how to find 37 (ten) in base eight, type in the correct answer at any point. |
| | br | 5-22-1 |
| 5-22-1 | qu | Look again at 37 (ten). We are looking for a way of regrouping it in terms of eights or powers of eight. What is the largest power of eight represented in 37 (ten)? |
| | ca | 8 to the first power |
| | ty | Correct |
| | ca | 45 (eight) |
| | cb | 45 |
| | ty | Good for you! 37 (ten) = 45 (eight) |
| | br | 5-23 |
| | nx | |
| | fn | 1f//50 |
| | wa | 8 to the first power |
| | un | Your answer is less than 50% correct. Try again. |
| | un | The correct answer is "8 to the first power." Eight raised to the second power or 64 is not contained in 37. Type "8 to the first power." |
| 5-22-2 | qu | How many groups of 8 are there in 37 (ten)? |
| | ca | 4 |
| | cb | four |
| | cb | Four |
| | ty | Correct |
| | ca | 45 (eight) |
| | cb | 45 |
| | ty | Good for you! 37 (ten) = 45 (eight) |
| | br | 5-23 |
| | un | 8 goes into 37 four times. Type four. |
| 5-22-3 | qu | Make a place value chart for base eight on a piece of scrap paper. Write 4 in the eights column. What is the remainder when you subtract 4 eights from 37 (ten)? |
| | ca | 5 |

```
LABEL    OPR MODE   ARGUMENT
            cb      five
            cb      Five
            ty      Correct
            ca      45 (eight)
            cb      45
            ty      Good for you!  37 (ten) = 45 (eight)
            br      5-23
            un      4 eights - 32   37 - 32 = 5.  Type 5.
 5-22-4     qu      Since there are no eights in this remainder, this
                    indicates the number of ones remaining.  Write 5 in
                    the ones column.  Now read the number.  What is 37
                    (ten) in base eight?
            ca      45 (eight)
            ty      Correct
            ca      45
            ty      Correct - 37 (ten) = 45 (eight)
            un      37 (ten) = 45 (eight)  Type 45 (eight).
```

*Starting with question 5-22, the above sequencing illustrates a remedial branch with a rather interesting twist. Preliminary work indicated that students sometimes get needlessly caught in a remedial branch because of a minor error or oversight. In addition, some students would discover their original mistake during the remedial sequence. So that such students would not have to pass through pointless remedial questions the "aha" feature was developed. An incorrect answer to 5-22 branches the student to 5-22-1, the first remedial question. Question 5-22-1 and each successive remedial question contains two ca-cb sequences. The first provides the answer to the remedial question itself, the second provides the answer to the original main question 5-22. If under any of the above remedial questions, the student typed the answer to the original question 5-22 [e.g., 45 (eight) or 45 ], he would be given the ty "good for you..." and branched out of the remedial sequence to the next main question 5-23, by means of the br 5-23.*

This sample program is representative of the kind of exercise that has been programed in the modern mathematics course. The rest of Chapter V covers such topics as transformations from one base to another, base eight, base five, base twelve, and base two number systems, and simple arithmetic operations in other number systems.

## Engineering Economics

Prepared by:

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Engineering Economics is a course for advanced undergraduate and graduate students who are primarily in the field of Industrial Engineering. However, the course is also offered to students in other engineering specialties. In addition, students in business majors who are interested in economic analysis frequently take the course as it is now offered on the Penn State campus. The content of the course includes such problems as investment, equitable return, and cost methods of analysis. The following sample of the course is taken from the beginning of Chapter IV entitled "Time Value of Money." The reader will note that compared to previous CAI courses, Engineering Economics places considerably more emphasis on the display materials used by the student in conjunction with the computer course. One objective for future research is to determine the effects on student learning of varying ratios of display and programed materials. Much of the display material for Engineering Economics will be put on slides and tape in the near future.

### Sample Program

```
LABEL   OPR MODE   ARGUMENT
 dl-0      rd      Read paragraph 04-01 (EOB)
```

---

Paragraph 04-01

The payment for factors of production. The classic economist lists the factors of production as land, labor, capital, and entrepreneur for which rent, wages, interest, and profit respectively are paid. The power to satisy human wants is called utility by the economist. The "land" has possession, place, and time utility. Land is defined as the attributes of nature, and in this sense is a much more encompassing thing than mere "extension" or space filling as we normally think of land. It also includes the "elementary" utilities endowed by nature; for example, the malleability, strength, appearance, and other characteristics of copper. Payment for the use of land is called "rent." (See interest below.)

The term "labor" includes all human effort expanded to add utility to an item. It includes the president of a corporation as well as the lowest paid worker or secretary. Direct labor is that which works on the product; whereas indirect labor is that which is rendering services to enable the production to take place. All of this labor is paid "wages" under economic theory. Form and time utility is added by factory or production employees. Warehousing adds time utility and transportation adds place utility. Owning the product or having the product (assignment, lease, or possession) adds possession utility.

The term "capital" refers to the machines, buildings, equipment, plans, patents, and all other means of adding utility to a good program. Used loosely it means all the funds, equipment, or property necessary to carry out mining, agriculture, manufacturing, transportation, and/or selling of the product. Used in this manner, it would include many things that the economist would classify as "land." In this text we will tend to use the looser term since it is more easily understood and is somewhat awkward to refer to raw material as part "land" and part "capital."

The student should be warned not to think of capital as just money. Money is a medium of exchange and a unit of measurement, and should be thought of in these senses. "Interest" is the payment for the use of capital. Later when we talk of the "return on the investment" we are usually talking of interest in its broadest sense. However, the word in context should show the breadth of its meaning. A few moments of reflection will usually suffice to clarify the meaning in the student's mind.

The concept of "entrepreneur" has come under a good deal of criticism during late years. The fact that corporation stockholders (owners) and managers (labor) each share some of the traditional characteristics of the entrepreneur seems to have confused the issue. However, if entrepreneur is thought of as a spirit or driving force in the organization, there need not be the confusion. In fact, "profit" sharing plans tend to classify the managers with owners and it is popular today to group managers with stockholders, so far as their interests are concerned. Businessmen class profits as income less all expenses and taxes, and for practical purposes this definition is sufficient. But we many times think of the profits in terms of "mathematical" interest. Here again the multi-meaning of the words should not cause confusion if the student is aware of the subtle nature of the use of these terms.

---

| | | |
|---|---|---|
| d1-1 | qu | The factors of production as listed by the classic economists are: _______, ______, _______, and ______. |
| | ca | land, labor, capital, entrepreneur |

```
LABEL   OPR MODE   ARGUMENT
           cb      land, labor, capital, and entrepreneur
           nx
           fn      st//90
           ca      land, labor, capital, entrepreneur
           nx
           fn      sf//50
           wa      land, labor, capital, entrepreneur
           un      You were less than 50% correct.
                   Try again.
```

*The above sequence illustrates the value of some of the partial answer functions for processing student responses several words in length. If the student should happen to give the correct answer as written in the first ca, the computer would immediately present the next question labeled d1-2. On the other hand, if the student's response does not match the original ca, the function fn st//90 is employed to process the student's answer. If the number of correct characters in the response equals or exceeds 90%, the function will be satisfied, and the student will be sent to the next question as if he had given an exact match. In this example, the author is allowing the student to make errors up to a maximum of 10%. This criterion would take care of minor errors such as misspellings, and minor differences in the punctuation of the response such as capital letters, commas, periods, and spaces. If the student makes more than the specified 10% errors, the first function is not satisfied and control passes to the second function, fn sf//50. The latter function again processes the student's response. If the response contains at least 50% correct characters, the correct elements of the response are typed out to the student with a dash for each erroneous character cueing the student as to the parts of the answer still required. If the student's response does not contain 50% correct characters, his response is picked up by the un which types out, "You were less than 50% correct. Try again."*

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| dl-2 | qu | For the factors of production; ________ is paid for the use of land, ________ are paid to labor, ______ is paid for the use of capital, and _______ is what the entrepreneur receives for his contributions to production. |
| | ca | rent, wages, interest, profit |
| | nx | |
| | fn | st//90 |
| | ca | rent, wages, interest, profit |
| | nx | |
| | fn | sf//50 |
| | wa | rent, wages, interest, profit |
| | un | You were less than 50% correct. Try again. |
| | un | Review paragraph 04-01 and try again. |
| dl-3 | qu | The economists say that the power to satisfy human wants is called utility. Land, for example, has _________, _______, and _______ utility. |
| | ca | possession, place, time |
| | nx | |
| | fn | st//90 |
| | ca | possession, place, time |
| | nx | |
| | fn | sf//50 |
| | wa | possession, place, time |
| | un | You were less than 50% correct. Try again. |
| dl-4 | qu | Human labor expended to add utility to an item is called ___________. |
| | ca | labor |
| | ty | Good. This includes all types of labor, whether it be direct or indirect. |
| | nx | |
| | fn | sf//80 |
| | ca | labor |
| | un | Try again. |
| | un | The correct answer is labor. |

| LABOR | OPR MODE | ARGUMENT |
|---|---|---|
| d1-5 | qu | All means of adding utility to a good program, other than labor, comes under the name of ______. |
| | ca | capital |
| | ty | Very good! As your display mentions, this includes such things as funds, equipment, property, etc. |
| | nx | |
| | fn | st//85 |
| | ca | capital |
| | un | Try again. |
| | un | The correct answer is capital. Type it in. |
| d1-6 | qu | The payment for the use of capital is called _______. |
| | ca | interest |
| | ty | Good. Remember that capital is not only money. Money should be thought of as a medium of exchange and a unit of measurement. |
| | nx | |
| | fn | st//85 |
| | ca | interest |
| | un | Try again. |
| | un | The answer is interest. Type it in. |
| d2-0 | rd | Read paragraph 04-02. (EOB) |

---

### Paragraph 04-02

Interest. Interest in the economic sense is

Gross interest = pure interest + inconvenience + expense + taxes. Pure interest is difficult to conceive of existing as an independent element. Perhaps the closest interest rate to pure interest is the Federal Reserve Board's discount rate, but even here there is some expense involved.

Inconvenience means that if funds are committed then they are not available for other investments. Therefore, in order to compensate for not having a possible opportunity to use the funds for a more desirable or lucrative purpose in the future, we say there is inconvenience. Also, a corporation could pay dividends to its stockholders or an individual could spend the funds for consumer goods which would yield satisfaction to the stockholders or individuals. The foregoing of these satisfactions is an inconvenience to the people concerned. The act of not paying dividends or spending funds for consumer goods is called "saving" and causes "inconvenience" in the economic sense.

The expense in gross interest is a real and tangible item. If money is loaned or investment made, there is work involved in investigating and justifying the loan or investment. There is also risk of loss which, if it occurs, is an expense.

Last is the element "taxes." Where there is income, there are likely to be taxes from some governing body. In fact, they are levied at the local, county, state, and federal levels, (and in some cases at an area level, e.g., the Port Authority of New York). A thorough knowledge of the effective tax laws is the only logical approach to the amount. We will discuss taxes in general later on, but the laws from location to location vary to such an extent that a satisfactory discussion of them take more time than is available.

---

```
d2-1    qu    The "interest" received as payment for the use of
              capital is divided by the economist into the following
              terms:
              pure interest
              inconvenience
              expense
              taxes
              The sum total of these terms is said to be the _______
              __________ received.
        ca    gross interest
        ty    Very good.
        nx
        fn    st//90
        ca    gross interest
        nx
        fn    sf//50
        wa    gross interest
        un    You were less than 50% correct.  Try again.
        un    Try again.
d2-2    qu    Of the components of gross interest, pure interest is
              probably the most difficult to isolate because it is
              hard to find exactly how much of the gross interest
              does not contain any form of inconvenience or expense.
              Of the remaining components (other than pure interest),
              which one would you say is the easiest one to isolate?
```

```
LABEL   OPR MODE   ARGUMENT
              ca   taxes
              ty   Very good.  Taxes are usually fixed and they depend
                   mostly on the location of the enterprise.  The loca-
                   tion of a new plant or warehouse is sometimes affected
                   by the taxes involved.  The idea is, of course, to
                   minimize the taxes involved so that the "return on
                   investment" (after taxes) is a maximum.
              wa   inconvenience
              ty   No.  Inconvenience is probably just as hard to isolate
                   as pure interest.  For example, the loss involved when
                   funds cannot be used for new investments because they
                   are already committed is very difficult to determine.
              wa   expense
              wb   expenses
              ty   No.  There is one that is still easier to isolate and
                   that is the element "taxes."  Type in the correct
                   answer.
              nx
              fn   sf//80
              wa   taxes
              un   Incorrect.  Answer either as inconvenience, expense,
                   or taxes.
              un   Try again.
 d2-3         qu   The risk of a loss in an investment, if it occurs,
                   is considered as an _______.
              ca   expense
              ty   Correct.  In all investments the risk of loss is
                   always present.
              nx
              fn   st//85
              ca   expense
              nx
              fn   sf//50
              wa   expense
              un   Incorrect.  Try again.
```

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
|  | un | The correct answer is expense. Type it in. |
| d3-0 | rd | Read paragraph 04-03. (EOB) |

---

Paragraph 04-03

Mathematical Interest. In mathematics interest is defined as a positive fraction rate of increase in respect to an investment. Thus, where

$P$ = the principal, amount invested, value of investment, or starting quantity as indicated in the problem

$i$ = interest rate expressed as a fraction

$I$ = monetary measurement (dollars, pounds, rubles, etc.) of the amount of interest received

$n$ = number of terms of the contract, investment, or consideration stated in the problem

then:

$$I = Pin$$

gives the "simple" interest for n periods.

Also:

where:

$S$ = sum accumulated after n periods

$$S = P + Pin$$

Since no one would be willing to give away the principal amount at the end of the contract or effective period, the sum must include the original principal.

The student should note that if $n > 1$ then the accumulated interest after the first period does not draw interest, yet it has value. If the interest after the first period is added to the principal and thereafter draws interest, it is known as "compound" interest.
Thus:

| Period | Principal | Interest | Sum end of Period |
|---|---|---|---|
| 1 | $P$ | $Pi$ | $P(1+i)$ |
| 2 | $P(1+i)$ | $P(1+i)i$ | $P(1+i)^2$ |
| 3 | $P(1+i)^2$ | $P(1+i)^2i$ | $P(1+i)^3$ |
| 4 | $P(1+i)^3$ | $P(1+i)^3i$ | $P(1+i)^4$ |
| ⋮ | ⋮ | ⋮ | ⋮ |
| n | $P(1+i)^{n-1}$ | $P(1+i)^{n-1}i$ | $P(1+i)^n$ |

or

((1)) $S = P(1+i)^n$ where $i \geq 0$

gives the compound interest formula. This is the basic formula from which other equations for valuation are derived. All the periods n in the equation are of equal extent. If the time is not divisible into equal periods, then the n is expressed as a decimal value, i.e., 3.5, 4.3, etc.

---

```
d3-1      qu      Paragraph 04-03 deals with the term: ____________
                  interest.
          ca      mathematical
          ty      Good.
          nx
          fn      st//90
          ca      mathematical
          nx
          fn      sf//50
          wa      mathematical
          un      You were less than 50% correct.  Try again.
          un      The answer is mathematical interest.
          br      d3-2
d3-2      qu      What is the formula for the amount of "simple" interest
                  after n periods?
          ca      I=Pin
          ty      Good.  This relationship is always used whenever the
                  amount of interest received after any number of periods
                  does not draw any interest.
          nx
          fn      sf//80
          wa      I=Pin
          br      t-t
          nx
          fn      sf//80
          wa      S=P+Pin
t-t       ty      Incorrect.  This equation will give you the total
                  amount of money you will have after you have been paid
```

```
LABEL   OPR MODE   ARGUMENT
                   in full for the use of your capital.  It includes the
                   original amount invested (referred to as the principal)
                   plus the amount of "simple" interest you will receive
                   after n periods.  Try again.
           un      You were less than 80% correct.  Try again.
           un      Review paragraph 04-03 and try again.
d3-3       qu      If you invested $100 and you were told that you would
                   receive a "simple" interest of 1% for every month that
                   you kept your money invested, how much money would you
                   have if you retrieved your investment after two months?
           ca      $102.
           cb      $102
           cb      $102.00
           ty      Correct.  This is a very simple problem and you could
                   probably do it mentally.  If you happened to write out
                   the relationship,it should look like this:
                           S=P+Pin=100+100(.01)(2)=$102.
                   where S is your accumulated sum after 2 periods (months).
           un      Did you forget the $ sign in your answer.  Try again.
                   Don't use the space bar.
           un      Use the following relationship:
                           S=P+Pin     where:
                           P=amount invested ($100)
                           i=simple interest (.01)
                           n=2 months or periods
           un      Try again.
d3-4       qu      When the interest earned (after any period is added
                   to the principal and is included in the computation
                   of interest for the following period, we are dealing
                   with __________ interest.
           ca      compound
           ty      Very good.  This is the standard method for computing
                   interest.  It is the way your bank will compute the
                   interest earned on your savings account.
           nx
```

```
LABEL   OPR MODE  ARGUMENT
          fn      st//90
          ca      compound
          nx
          fn      sf//50
          wa      compound
          un      You were less than 50% correct.  Try again.
          un      Incorrect.  When this method of computing interest is
                  used, it is called compound interest.  Type in the
                  correct answer.
 d3-5     rd      We shall digress for a moment from the display material
                  in order to clarify something about notation.  If you
                  are familiar with standard typewriters, you will notice
                  that they do not provide for the writing of subscripts
                  or exponents.  Unless the carriage is offset, all
                  characters will appear on the same line.  The material
                  on your display shows exponents in the proper position
                  but that is because they were carefully placed there
                  at the time of typing.  At the typewriter terminal a
                  different notation will be used in order to allow all
                  characters to fall on the same line.
                  1.  We shall represent multiplication by means of a
                      single asterisk (*).
                  2.  We shall raise numbers to the desired power by
                      means of a double asterisk (**).
                      For example:
                      1.  If you want to multiply n by 2, we shall write
                          it as:  n*2
                      2.  If we want to square n, we shall write it as:
                          n**2
                      This notation will be used only when the use of
                      exponents requires it.  (EOB)
```

*The above question illustrates one of the minor problems that has been encountered in programing the quantitative courses. The implication in the above statement that the* *typewriter terminal cannot be used to input exponents or subscripts is incorrect. A separate typehead containing mathematical symbols is available, but it requires some reorientation with regard to the standard typewriter keyboard. In addition, if these symbols were to be made available, the typeheads would have to be manually switched at this point. Rather than be bothered with this procedure, the present author decided to express his equations in Fortran notation, especially since he wanted his students to learn this notation anyway. The use of the mathematics typehead is being explored in several courses, and key tabs may eventually be developed to aid the student in locating the appropriate symbols on the typewriter keyboard.*

| | | |
|---|---|---|
| | qu | How would you write 2 times, i squared? |
| | ca | 2*(i**2) |
| | cb | 2*i**2 |
| | ty | Good. Always remember that in mathematics the order of computation is the following:<br>a. exponents have priority over multiplication, division, addition, and subtraction<br>b. multiplication and division have priority over addition and subtraction<br>c. additions and subtractions are done last |
| | wa | (2*i)**2 |
| | ty | This would be correct if you interpreted the question as 2 times i, squared. Notice the comma. This is to avoid ambiguity. Type the answer as 2*(i**2) |
| | un | Do not leave any spaces in your answer. Try again. |
| | un | The correct answer is 2*(i**2). Type it in. |
| d3-6 | qu | How would you write equation ((1)), in paragraph 04-03, if you used the notation? |
| | ca | S=P*((1+i)**n) |
| | cb | S=P*(1+i)**n |
| | ty | Good. Always try to use parenthesis to isolate terms as required by the mathematical expression. It is |

```
LABEL   OPR MODE  ARGUMENT
                  better to have extra parenthesis (as long as they are
                  placed correctly) if it will help to visualize the
                  terms.
            un    Incorrect.  Did you use capital S and capital P?
                  If not, do so.  Leave no spaces between characters.
            un    The correct form would be:
                        S=P((1+i)**n)
 d3-7       qu    The relationship S=P*((1+i)**n) is called the _______
                  ________ formula.
            ca    compound interest
            ty    Correct.  This is a good formula to keep in mind
                  because from it we derive other equations for valuation.
            nx
            fn    st//80
            ca    compound interest
            nx
            fn    sf//50
            wa    compound interest
            un    You were less than 50% correct.  Try again.
            un    Review paragraph 04-03 and try again.
            un    The correct answer is:  compound interest formula.
            fn    wait//5
            br    d4-0
 d4-0       rd    Read paragraph 04-04.  (EOB)
```

---

### Paragraph 04-04

Compound Amount, Uniform Payment, Uniform Time Period. Consider the case where a uniform amount R is paid (or received) at the end of uniform periods 1, 2, 3, ---, n at the interest rate i. Then the payment at the end of period 1 will amount to $S_1$ at the end of period n; the payment at the end of period 2 will amount to $S_2$ at the end of period n, etc., until the last payment at the end of period n will be $S_n$. Also, let the sum of all these payments equal S. We can then say:

$$S = S_1 + S_2 + S_3 + \text{----------------} + S_n$$

but:

$$
\begin{aligned}
S_n &= R \\
S_{n-1} &= R(1+i) \\
&\vdots \\
S_3 &= R(1+i)^{n-3} \\
S_2 &= R(1+i)^{n-2} \\
S_1 &= R(1+i)^{n-1}
\end{aligned}
$$

and

((2)) $S = R + R(1+i) + - - - - + R(1+i)^{n-3} + R(1+i)^{n-2} + R(1+i)^{n-1}$

multiplying both sides of equation ((1)) by (1+i):

((3)) $S(1+i) = R(1+i) + R(1+i)^2 + - - - - - - + R(1+i)^{n-2} + R(1+i)^{n-1} + R(1+i)^n$

then subtracting ((3))-((2)):

$$S(1+i) - S = R(1+i)^n - R$$

$$S + Si - S = R((1+i)^n - 1)$$

((4)) $S = R\left[\frac{(1+i)^n - 1}{i}\right]$

Equation ((3)) has the factor $\frac{(1+i)^n - 1}{i}$ which is shown in compound amount-sum of the series table. It is also called the future value of an annuity.

---

| | | |
|---|---|---|
| d4-1 | qu | In this paragraph we are dealing not with a single payment but with a _______ of payments all of which are ________ and paid (or received) at the end of uniform periods. |
| | ca | series, equal |
| | ty | Very good. It is very important to keep in mind the fact that the payments are made at the end of the period. The formulas we are dealing with are derived for this situation. |
| | nx | |
| | fn | sf//90 |
| | ca | series, equal |

```
LABEL   OPR MODE   ARGUMENT
           nx
           fn      sf//50
           wa      series, equal
           ty      Less than 50% correct.  Try again.
           nx
           fn      sf//50
           wa      group equal
           ty      Instead of the word "group," "series" would be a
                   better word because it is the one that is frequently
                   used.  Type in the correct answer as:  series, equal
           un      You were less than 50% correct.  Try again.
           un      Review paragraph 04-04 and try again.
           un      The correct answer is:  series, equal.  Type it in.
d4-2       qu      The last payment, made at the end of period n, will
                   accumulate an amount of interest equal to ________.
           ca      0
           cb      zero
           ty      Correct!  Since the last payment is made at the same
                   time that the last period ends, it does not have time
                   to accumulate interest.  The final payment only adds
                   to the total sum of the series an amount equal to R.
           wa      Ri
           wb      iR
           ty      Wrong.  The last payment is made at the same time that
                   the last period ends and therefore it does not have
                   time to accumulate interest.  At least one period must
                   pass before any interest is paid on the given payment.
                   This last payment only adds to the total sum of the
                   series S an amount equal to R.  The correct answer
                   to the question is zero.
           un      Incorrect.  Try again.
           un      Hint:  How many periods will this last payment be
                   allowed to accumulate interest?
           un      The correct answer is zero.  Type it in.
```

| TAPE | OPR MODE | ARGUMENT |
|---|---|---|
| d4-4 | rd | How would you write equation ((4)) using the notation discussed previously? Write out your answer on a piece of paper and then press EOB to compare with the correct answer. |
| d4-5 | qu | The answer is: S=R*((1+i)**n-1)/i.<br>Equation ((4)) is called the ______ ______ ______ ______ ______. |
| | ca | future value of an annuity |
| | ty | Correct. This is the equation that will give you the total sum of a series of uniform payments after n periods. This equation contains the factor: ((1+i)**n-1)/i. This factor is often called the uniform series compound amount factor and is usually abbreviated as series compound amount factor. |
| | nx | |
| | fn | st//90 |
| | ca | future value of an annuity |
| | nx | |
| | fn | sf//50 |
| | wa | future value of an annuity |
| | un | You were less than 50% correct. Try again. |
| | un | Incorrect. Read the last two sentences of paragraph 04-04 and try again. |
| | un | Try again. |

## Cost Accounting

Prepared by:

Joe J. Cramer, Jr. and Charles Smith

### Introduction

The cost accounting course being developed is formally classified as the basic management accounting course at The Pennsylvania State University. The completed course as developed for computer presentation is based on two major sources of data. Certain portions of the course are based on text materials adopted for current use at Penn State. Appreciation is expressed to McGraw-Hill Book Company, Inc., I. Wayne Keller, and William L. Ferrara (publisher and authors of the second edition of Management Accounting for Profit Control) for granting permission to use these materials in the research project. "Supplementary Reading Assignments" have been written by the course author and distributed to student subjects (as well as students formally enrolled for college credit) for the purpose of expanding and clarifying important accounting concepts and procedures which empirical evidence suggests as being not readily comprehended by many undergraduate students of cost accounting. The objective of the teacher of the basic management accounting course--whether this creature assumes the form of an IBM 1410 computer system or the traditional classroom lecturer--is to provide an opportunity for each student to gain exposure to selected theoretical aspects of management accounting theory and their role in management planning and control coupled with simulated practical experience (homework problems) which, hopefully, reveals advantages and disadvantages of both conceptual observations and practical applications.

## Development of Cost Accounting Course for Computer Presentation

Implicit in the above comments is the fact that management accounting data are vital to decision-making for profit optimization. Consequently, information which facilitates cost control (with implications for cost reduction) is the sine qua non on which a management accounting system rests. The completed course, as originally programed, includes the following topics (ten chapters):

I. Introduction to Management Accounting
  A. The responsibility of accounting and duel posting concepts in relation to cost accumulation for (a) control and (b) income measurement permeate the entire course.
  B. Distinction between accounting procedures for merchandising and manufacturing firms.
II. The Cost Accounting Cycle (accounting for materials, labor, and overhead)
III. Basic Cost Accounting Systems (historical and standard costing systems)
  A. Job Order Costing
  B. Process Costing

IV. Control of Manufacturing Costs (classification of costs as fixed, variable, and semi-variable for control purposes and usefulness of the flexible budget technique for control of factory overhead costs).

Since the project began, curriculum changes have been instituted by the accounting department. Some of these changes will be incorporated into the revised cost accounting CAI course.

Ten chapters have been prepared for CAI. Extensive revision of the material will be made during the summer and fall terms. Revisions will be based on a review of files maintained for student subjects and improvements visualized by the author and his graduate assistant. Necessity for revision of the cost accounting course is traceable to four major factors which are briefly explained as follows:

(1) Original plan to develop course from classroom text materials: Even though a text is required for students, much of the knowledge disseminated in the usual classroom situation results from lectures presented by the instructor. Thus, all students are exposed to a broader coverage rather than being limited to consideration of subject matter as treated in the text. Implications of this observation for development and presentation of materials for CAI may be summarized as follows. Rigid reliance on text materials alone would severely limit the teaching effectiveness of a course developed for CAI. More specifically, if this is the case, student subjects would not receive as much depth of coverage as their classroom counterparts.

Course authors can overcome the above straitjacket by either preparing supplementary reading assignments or by requiring library reading assignments. As indicated above, the former technique is used to expand the cost accounting course, and more supplementary reading assignments are being prepared. Important by-product of this procedure is that exposure of students is broadened in a fashion similar to that of students of the traditional classroom mode. In this way teaching methods peculiar to the course author are imposed on students via the computer. In addition, such explanatory reading assignments will reduce student frustrations and lend flexibility to the course author in developing materials for CAI.

(2) Revisions based on student testing of program: Valuable suggestions and information for revising courses are received by (a)

communicating with students, and (b) reviewing computer printouts contained in their files. Obviously, the task of revising materials from this type information is a continuous one. Wherein part (1) may be used to recognize individual differences of the course author, revisions based on student testing of programs should enable the course author to develop materials with sufficient generality and flexibility to fit the individual needs of students.

(3) Utilization of additional operation codes: In view of substantial improvement and expansion of the Coursewriter language since initiation of the research project, future revisions of the program will incorporate the more recent operation codes.

(4) Incorporation of quizzes, examinations, and problems in the program: The completed version of the revised cost accounting program will include quizzes, examinations and additional case problems.

## Reaction of Students

The following comments are based on observations of students who tested parts of the cost accounting program during fall term (1964). Fifteen students who were concurrently enrolled in the course for college credit volunteered to serve as subjects during the fall term. Portions of Chapters 1, 2, 3, and 6 of the program were tested. Students indicated that they were initially fascinated by CAI and impressed by the large degree of student independence which characterizes the learning situation as well as the ability to proceed at their own pace. Three students informed the course author that for the first time during their college careers they were able to ask meaningful questions in class as a result of reviewing computer printouts.[1] In addition, students expressed great satisfaction for being given an opportunity to participate in a research project with their classroom instructor. This type of student-teacher association (at the larger university) is usually limited to the graduate student.

Several students became bored after having worked at the computer for a few sessions. Discussions with these students revealed the following reasons for this situation: (1) Inability to proceed at the same pace as formal classroom assignments because of constraints on computer time and facilities, and necessity to, in effect, prepare "two" assignments--one for actual course credit and the other for the research project. Demands on students' time in view of enrollment in other courses thus accounts for part of this reaction. Some students were nervous because of exposure to a new teaching medium or inability to type as proficiently as they would have liked, coupled with the mere idea of having to "operate a machine." Most students subsequently adjusted to CAI if (1) they were permitted to work alone, and (2) if someone was available in case of "difficulty" with hardware and course content.

---

[1] These observations may not be applicable in situations where students are exposed to CAI only.

Revision of the existing cost accounting course will be undertaken on the basis of the four factors cited above. Such revisions will take the form of a more extensive utilization of new *Coursewriter* operation codes and inclusion of more acceptable answers, etc., as revealed by student subjects' files. In order to expand and adapt the course into a more "complete package" for experimental purposes, additional case problems will be programed as well as quizzes and examinations.

### Sample Program

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| 7-1 | rd | In order to proceed through this section of the course dealing with accounting procedures under an actual or historical cost system, you should have read Chapter 7 of the text and the Supplementary Reading Assignment for Chapter 7. Read Display 7-1; press (EOB) when you are ready to begin. |

---

### Display 7-1

The following outline should serve as a guide to the *substantive content* of the section of the course dealing with accounting procedures under an actual or historical costing system. Later you must be able to reconcile such a system with the standard cost system which will be introduced after this section of the course.

(1) You must learn the nature and significance of the two basic cost accounting systems in addition to accounting procedures relevant thereto. For example:

  (a) How are the basic journal entries determined?
  (b) How does the *responsibility accounting concept* relate to each of the basic cost accounting systems?

(c) What is the relationship of the general (control) and subsidiary (supporting) ledgers (or records)?
(d) What is the appropriate accounting treatment for spoiled units?

(2) With respect to process costing, the following procedures and concepts are emphasized:

(a) Learn to distinguish the two methods of process costing (the average cost method from the first in, first out method). You must become equally competent in applying both methods to problem situations.
(b) The concept of an equivalent unit (and the idea of stage of completion).
(c) Unit cost determination (for example, compare and contrast unit cost determination under the two basic cost accounting systems).
(d) Accounting treatment of costs associated with units transferred from one producing department to another, i.e., the effect of the transfer cost or costs of prior departments or unit cost determination.

You will probably find it necessary to read the assigned material more than once. Don't hesitate to do so!

---

```
7-2      qu      What are the two basic cost accounting systems?
         xl      180
         ty      Try to work faster.
         ca      job order costing, process costing
         ty      Correct.
         nx
         fn      kw//2
         ca      ,job order,process
         un      Remember that one system is used if goods are produced
                 to customer specification and the other if goods are
                 produced for stock.  Try again.
```

*There are several interesting aspects of the coding in the above question block. The operation xl 180 following the question specifies a time limit of 180 seconds for the student's response. If a response is not given within 180 seconds, the computer will type the following ty "Try to work faster."*

*The sequence is also a good illustration of the use of the keyword function. The correct answer is "job order costing, process costing"; however, if the student responds with the key words "job order" and "process" as indicated beneath the fn kw//2, his answer will be regarded as correct. The un in the above sequence also shows how a typeout can be included following an unanticipated incorrect answer to provide a clue to the correct answer.*

```
7-3     rd      There are six basic entries in an actual or historical
                cost system.  Recall that the predetermined factory
                overhead rate was introduced earlier.  Thus, entries
                must be made for actual as well as applied overhead.
                You will now be given a short quiz on the basic journal
                entries.  Be sure to use the dr. (debit) and cr.
                (credit) notation.  Press (EOB)
7-4     qu      What is the basic entry to record use of direct
                materials?
        nx
        ad      -cl//cl
        ca      dr. work in process, cr. raw materials inventory
        cb      dr. work in process, cr. raw materials
        ty      Correct
        nx
        fn      st//80
        ca      dr. work in process, cr. raw materials inventory
        un      Less than 80% correct.
        ad      -1//cl
        br      7-5
7-5     qu      What is the basic entry to record direct labor?
        ca      dr. work in process, cr. accrued payroll
        ty      Correct
        nx
        fn      st//90
        ca      dr. work in process, cr. accrued payroll
        un      Less than 90% correct.
```

```
LABEL   OPR MODE   ARGUMENT
          ad       -1//cl
          br       7-6
 7-6      qu       What is the basic entry to record actual factory
                   overhead?  Assume that indirect materials and indirect
                   labor have been used during the period, and make your
                   entry accordingly.
          ca       dr. actual factory overhead, cr. raw materials
                   inventory, cr. accrued payroll
          cb       dr. factory overhead, cr. raw materials, cr. accrued
                   payroll
          ty       Correct.  Note that in the entry to record actual
                   factory overhead, one or more of three types of accounts
                   are usually credited, viz., asset, valuation or contra,
                   and liability.
          nx
          fn       st//80
          ca       dr. factory overhead, cr. raw materials, cr. accrued
                   payroll
          un       Less than 80% correct
          ad       -1//cl
          br       7-7
 7-7      qu       The preceding entry may be expanded to include
                   depreciation of equipment as an element of factory
                   overhead.  How would this entry be made?  (Assume
                   that depreciation is the only element of factory
                   overhead in your answer.)
          ca       dr. actual factory overhead, cr. allowance for
                   depreciation of equipment
          cb       dr. factory overhead, cr. allowance for depreciation
                   of equipment
          ty       Correct.  Notice that in this instance a contra or
                   valuation account is credited.
          nx
          fn       st//75
          ca       dr. overhead, cr. allowance for depreciation of
                   equipment
```

```
LABEL   OPR MODE   ARGUMENT
           un      Incorrect
           ad      -1//cl
           br      7-8
 7-8       qu      What is the entry to record factory overhead applied
                   to production?
           ca      dr. work in process, cr. applied factory overhead
           ty      Correct
           nx
           fn      st//90
           ca      dr. work in process, cr. applied overhead
           un      Incorrect
           ad      -1//cl
           br      7-9
 7-9       qu      What is the entry to transfer completed units to
                   finished goods?
           ca      dr. finished goods, cr. work in process
           cb      dr. finished goods inventory, cr. work in process
           ty      Correct
           nx
           fn      st//90
           ca      dr. finished goods, cr. work in process
           un      Less than 90% correct
           ad      -1//cl
           br      7-10
 7-10      qu      The last entry is made to record cost of units sold.
                   How is it made?
           ca      dr. cost of goods sold, cr. finished goods
           cb      dr. cost of goods sold, cr. finished goods inventory
           ty      Correct
           nx
           fn      st//90
           ca      dr. cost of goods sold, cr. finished goods
           un      Incorrect
           ad      -1//cl
           br      7-11
```

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| 7-11 | qu | You have finished the quiz. You may ask for your score by typing the word "score" (without quotation marks). |
| | wa | score |
| | wb | Score |
| | ty | Your total number of errors on the seven questions is: |
| | fn | dc//-c1 |
| | ty | If you made two (2) or more errors, you will be branched back to the quiz. Before taking the quiz again, study Display 7-2 in which a schematic flow chart of the basic journal entries is presented. |
| | br | 7-3//c1//2 |

*The prior questions 7-3 through 7-11 illustrate how a short quiz may be programed, and how conditional branching can be accomplished based on the student's performance on the quiz. First of all note that the partial answer function used in each question was short test st which accepts an answer as correct if the specified percentage of correct characters is satisfied, but does not provide feedback to the student if his answer is wrong. Since this segment was considered to be a test for evaluation purposes, following each wrong answer the ad command instructs the computer to add -1 to Counter 1. Furthermore, the student is only allowed one response per question in this sequence since it is desirable to move the student through the quiz as rapidly as possible. This is accomplished by placing a branch to the next question immediately following the ad operation. Following the last test question, the student may ask for his total number of errors by typing "score." The score is then displayed by the function display counter, fn dc//-c1 which is read "display minus the contents of counter 1." Just below this function is the conditional branch which branches the student back to the beginning of the quiz and instructs him to read display 7-2, i.e., br 7-3//c1//2 is read "branch to label 7-3 if the contents of counter 1 added to 2 is zero or negative."*

| LABEL | OPR MODE | ARGUMENT |
|---|---|---|
| 7-12 | rd | Recall that the last two entries reflected (1) the transfer from work in process to finished goods, and (2) the transfer from finished goods to cost of goods sold. Determination of the dollar amount of these transfers is the main subject of this chapter. In succeeding portions of this section of the course it will be shown that the major difference between job order and process cost accounting is the way in which the transfers are calculated. Press (EOB). |

<u>Sample of Student's Typeout</u>

caexpl
(All Student Responses are Indented to the Right)

```
     (EOB)
make a request
     course
06/02/65   19:16
type your student number
     s0393
Carol 1     type course name/version number
     caexpl
Read the introductory material to Chapter 7, paragraphs 1 through 5.
When you have finished reading press (EOB).
What are the two basic cost accounting systems?
     job order, process
job order -------, process -------
     job  ordercosting, process costing
job order costing, process costing
     job order costing, process costing
Correct.
THERE ARE SIX BASIC ENTRIES IN AN ACTUAL COST SYSTEM.  Recall that the
predetermined factory overhead rate was introduced in Chapter 6.  THEREFORE
IT IS NECESSARY TO ACCOUNT FOR ACTUAL AS WELL AS APPLIED FACTORY OVERHEAD.
In the following questions you are required to record account titles for
```

```
the entries specified.  Precede each account title by appropriate dr.
(debit) or cr. (credit) notation.  For example, the entry to record raw
materials purchased for cash would be:  dr. raw materials inventory, cr.
cash.  What is the basic entry to record direct material usage?
     work in process, dr., cr., raw inventory
dr. work in process, cr. raw ------- inventory
     dr. work in process, cr. raw materials inventory
Correct.
What is the basic entry to record direct labor?
     dr. work in process, cr. accrued payroll
Correct.  Good timing.
What is the basic entry to record actual factory overhead?
Assume that indirect materials and indirect labor have been used during
the period, and make your entry accordingly.
     dr. actual factory overhead, cr. raw materials inventory, cr. accrued
     payroll
Correct.  Note in the entry to record actual factory overhead, three
types of accounts are usually credited, viz., asset, valuation or contra,
and liability.  Go to the next question.
The above entry may be expanded to include depreciation of equipment as an
element of factory overhead.  How would an entry of this type be made?
     dr. factory allowance for depreciation
Less than 100% correct; try again.
     dr. facotry expense,cr. allowance for depreciation of equipment
Less than 100% correct; try again.
     dr. factory overhead, cr. allowance for depreciation of equipment
Correct.  Note that, in this instance, a contra or valuation account is
credited.
You may now ask for your score by typing the word score.
     score
Your number of errors is (i.e., the number of times you failed to meet
the specified percentage):
2
If you made 4 or more errors,you will be branched back to the beginning.
You are finished--please sign off now.
     Off
You have been signed off.
  ***signed off at 19:27***
```

# CHAPTER IV

# PRELIMINARY STUDIES OF STUDENT RESPONSES TO COMPUTER ASSISTED INSTRUCTION

During the course of the project, approximately 67 Penn State students have completed sections of the four CAI courses. The computer time uses for student trials amounted to approximately 200 hours. The purpose of the present chapter is to describe some of the preliminary results obtained with these students.

The total group of students may be divided into two subgroups of 47 and 20 students respectively. The first 47 students were used to help test courses early in the investigation prior to the development of achievement criterion measures. For this group, the variables available for analysis were

1. Self-report ratings of reactions to CAI.
2. Student errors in CAI courses.
3. Rate or speed of performance on course material.
4. Scholastic Aptitude Test scores (SAT).
5. Cumulative grade point average.
6. Scores on the Penn State entrance examination battery and various subtests.
7. Scores on the Bernreuter Personality Inventory administered to entering freshmen at Penn State.

For the second group of 20 students, measures of achievement of course content and retention were obtained in addition to the above variables.

## Reactions of Students to CAI

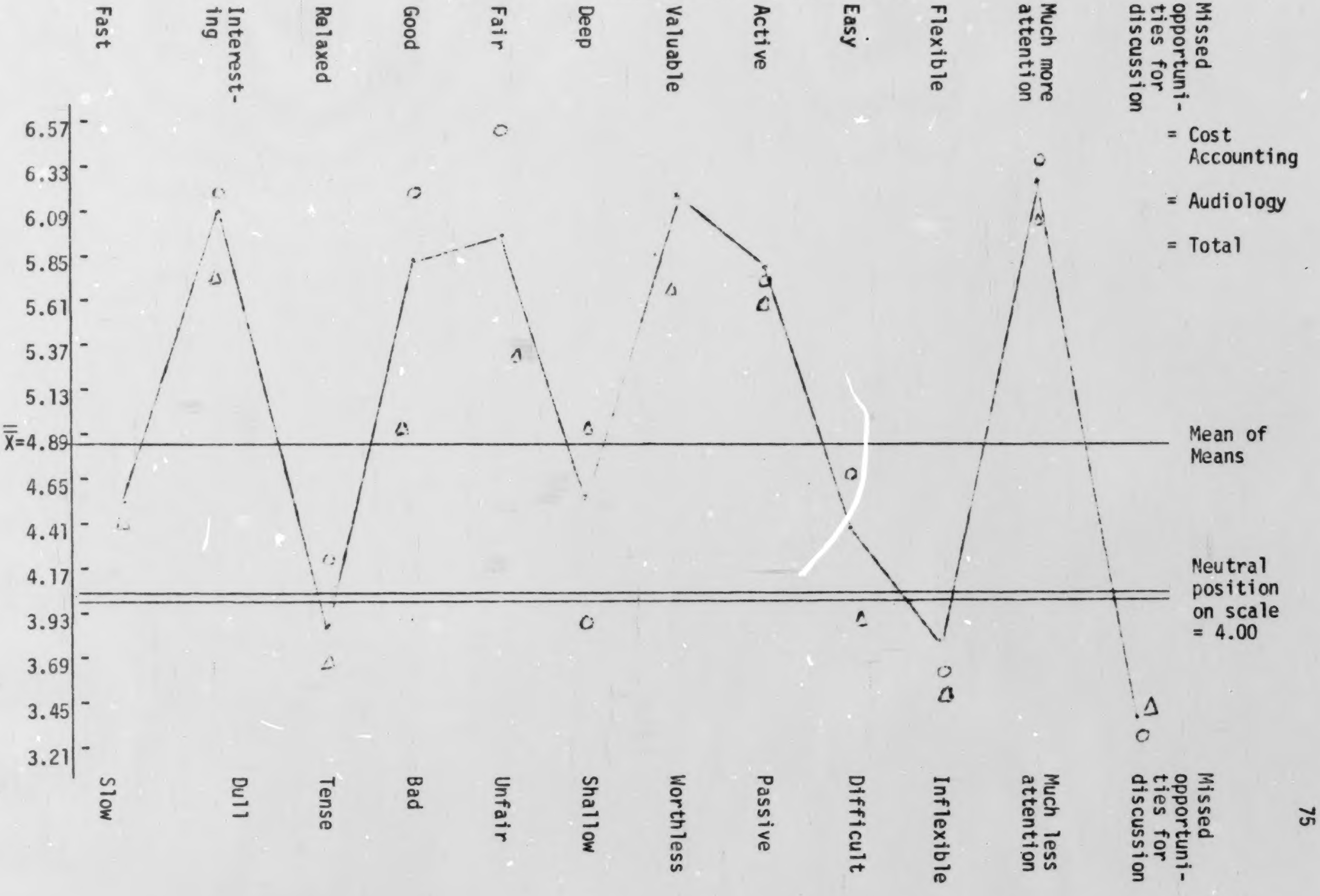
The results for 47 students are included in the first analysis. Of the total of 47 students, 18 worked in audiology, 21 in cost accounting, 7 in modern mathematics, and 1 in engineering economics. The results fall into three general categories: 1) Mean student self-reports of reactions to CAI, 2) Selected correlations among a number of student variables and performance in CAI, and 3) Impressions as obtained from guiding students through the courses and from informal interviews with students following their experience with CAI. The results should be regarded as tentative and suggestive of hypotheses for further study under highly controlled conditions. The 47 students were the first pilot group to test the CAI courses. They are not a random sample of college students, nor were they assigned at random to the four courses. Frequently the students were used to help "debug" the courses, and problems were encountered by the student which would not ordinarily occur with a finished course. In addition, these early results are primarily of a correlational and descriptive nature with the accompanying difficulties of determining the direction of causation. In spite of the above qualifications, there appear to be some meaningful differences among the scales of the student reaction inventory, and some clusters of intercorrelations which "make sense" and support our subjective impressions.

Following his first session of CAI, each student completed a Student Reaction Inventory consisting of a number of scales modeled after the Semantic Differential (Osgood et al, 1957). The Student Reaction Inventory and other measuring instruments developed for this investigation have been reproduced in Appendix A (p. 93). The extremes of each scale are defined by pairs of bi-polar adjectives such as good-bad, dull-interesting, tense-relaxed, etc. Thirty-one students completed the reaction inventory (the first 16 students were taught prior to the development of this device). The intent for the future is to administer the inventory at the end of every five instructional sessions in order to obtain some longitudinal data on student attitudes towards CAI. In addition, achievement tests are being developed to assess the student's achievement of course content.

A profile of the mean ratings on twelve attitude scales was constructed for the total group, and separately for each course. This profile is shown in Figure 2 (p. 75). An examination of the high points on the profile of student attitudes toward CAI indicates that students found the experience highly interesting, good, fair, valuable, and active, and that the students reported being able to give the machine more attention than a traditional classroom lecture.

That students react favorably to a new and novel instructional technique such as CAI is reassuring, but not particularly surprising. The low points in the profile of student reactions may be of greater

Fig. 2. Profile of Mean Student Reactions to CAI



importance in pointing the way to improvements in the instructional system and toward new instructional strategies. The three lowest points in the profile indicated that the students reported being relatively tense as opposed to relaxed, they reported the program to be inflexible, and that they missed opportunities for discussion. Fifty-four per cent of the sample reported being "slightly tense" during the first session of CAI. We have no decisive data at present to indicate whether the reported tension had a positive or negative effect on student achievement and retention. It appears that some students are simply highly motivated to do well in the course, while others get flustered by the machinery.

The student self-reports seem to agree with informal observations of students working at the terminal. Some students seem "machine shy" during the first hour of instruction, and comments such as "I'm afraid I'll do something wrong," or "I'm afraid I'll break the machine," are quite common. Students usually report being more relaxed at the end of the first session of instruction. Other students seem to be in awe of the equipment during the first few instructional sessions. Several students who were personally observed by the writers became so engrossed that they forgot to follow a simple direction which had been stated some fifteen times in the program. These observations have led us to consider the need for longer warm-ups or an introduction to CAI which would prepare the student for instruction.

The report of program inflexibility seems to have resulted from the requirements of an earlier CAI system which required a perfect correct answer match. Answers which were essentially correct, but differed in some trivial character (frequently unnoticed by the student such as spaces, upshifts and downshifts, etc.) were judged incorrect by the machine. A computer which will not ignore trivial characters such as commas, periods, spaces, etc., and correctly evaluate a correct answer is judged inflexible by students. These reports emphasize the need for partial answer processing in CAI systems. It is anticipated that the ratings of future groups of students will indicate greater course flexibility as more of the functions permitting partial answer processing are incorporated into the courses.

Students also rated the machinery as quite "fast." This reaction raises the question of the rapidity of CAI. CAI frequently appears to qualify as an instance of massed practice. Although the system is in theory student-paced, the immediate presentation of the next question following a correct answer paces the student. A study is presently underway to investigate the effects of atudent-controlled pauses in the presentation of the course. Unfilled delays might provide time for students to process information and to rehearse their reponses, and might be especially valuable following the correction of an error.

## Correlations among Selected Student Variables, Reactions to CAI and CAI Performance Variables

A missing data correlational analysis of a matrix of variables including student errors, rate of performance, SAT scores, cumulative grade point average, Bernreuter personality scales administered to all entering freshmen at Penn State, student reactions to CAI, etc., was prepared. The analysis was performed for the total group of 47 students and separately for students in audiology and cost accounting. Keeping in mind the difficulties of *a posteriori* "data snooping," the writers examined the matrix in an attempt to find non-chance, meaningful clusters of correlation coefficients. The results reported here are those which in the writers' judgment seemed to tie together.

Although there are probably few individuals working in CAI who question the educational advantages of partial answer processing, some of the present results make quite clear the problem of the non-matched correct answer from the student's viewpoint. (The present data were obtained prior to the availability of partial answer processing.) In scoring the student's record for errors, it was necessary to distinguish between legitimate content errors, and what were called correct answers entered in wrong form which were regarded as incorrect by the computer. The mean per cent content errors based on the students' total number of responses for all courses was 20 per cent while the mean per cent correct answers entered in wrong form was 17 per cent. The correlations between the two types of errors were positive and significant at less than the .001 level for the total group and within each course. This correlation reflects the fact that the student types in the correct answer in wrong form, tries the same answer once or twice more just for good measure, and then discards his original correct answer for an incorrect response, thus making a content error. Some persistent students may type in their original correct answer again and again. When a number of questions was used as the base for computing the percentage of errors, several students exceeded 100%. An additional problem is that these persistent students may be the self-sufficient students, and the system is negatively reinforcing self-sufficient behaviors. The Bernreuter Stability and Self-sufficiency scales correlated significantly and positively with the percentage of correct answers entered in wrong form (.43 and .56 respectively). The manual for the Bernreuter describes the measure of self-sufficiency as follows: "Persons scoring high on this scale prefer to be alone, rarely ask for sympathy or encouragement, and tend to ignore the advice of others. Those scoring low dislike solitude and often seek advice and encouragement."

Although the problem of correct answers in wrong form can be minimized by specific instructions to students at the beginning of a course or by inserting additional correct answers, some wrong form errors result from typing habits and poor punctuation. A correlation of .35 (P=.05) between the number of lines of program covered by a student per hour and a Punctuation subtest score on the Penn State entrance examination was obtained. Furthermore, a negative correlation of -.26 approaching significance between Punctuation scores and percentage of wrong form errors was also obtained. Recently, a small group of eight students was administered an achievement test after completing a section of audiology. Just one or two "bugs" in the program, particularly of the correct response-wrong form type, seemed to produce much interference and large decrements in student learning. These results emphasize the importance of exposing students to a smooth-running CAI course. It is anticipated that the partial answer functions described earlier in Chapter III (p. 11) should alleviate the problems encountered due to requiring a student to match an anticipated answer exactly.

The correlations in Table 2 (p. 79)(shown for the total group and cost accounting in parentheses), generally indicate that students having lower cumulative grade points, and scoring lower on the entrance battery tended to rate the course and machine as "fast." The correlations of several subtests from the Penn State entrance battery with percentage of content errors are suggestive of a similar negative relationship, although they are less consistent. These data are indicative of the importance of the speed factor, and suggest that courses employing optional delays, optional review, and optional remedial work would be beneficial for some students.

## Performance of High and Low Aptitude Students in CAI

The second pilot study employed a sample of 20 students from introductory educational psychology classes, who were asked to volunteer for the experiment. The sample consisted of 12 high aptitude Ss and 8 low aptitude Ss as measured by the Scholastic Aptitude Test. High and low aptitude was defined as the upper and lower 25% of the distribution of verbal SAT scores. The test had been administered to the students upon entrance to the University. The performance of this group of Ss was studied in a much more systematic manner than that of the initial group of 47 students.

TABLE 2

Correlations among Some Cognitive Measures, Reactions to the Speed of CAI, and Percentage of Content Errors (n = 21)

| | | Penn State Entrance Exam Subtests (Moore-Caster) | | | | |
|---|---|---|---|---|---|---|
| | C.C.P.A. | Vocab | Paragraph Reading | Spelling | Punc. | Total |
| Rating: | | | | | | |
| Course Fast | -.15<br>(-.50)** | -.27<br>(-.51)** | -.33<br>(-.29) | -.14<br>(-.43)* | -.08<br>(-.12) | -.30<br>(-.37) |
| Machine Fast | -.35*<br>(-.69)** | -.37*<br>(-.44)* | -.37*<br>(-.49)* | -.31<br>(-.46)* | -.11<br>(-.24) | -.32<br>(-.38) |
| Per cent Content Errors | .13<br>(-.12) | -.20<br>(-.36) | -.11<br>(-.27) | .06<br>(-.48)** | .08<br>(-.30) | -.26<br>(-.45)* |

* $P < .10$
** $P < .05$

Each subject was scheduled for three sessions at the CAI Laboratory. During the first session, the S was given a warm-up at the instructional terminal in the early afternoon of the day he was scheduled to participate in the experiment. Previous experience with students suggested that some warm-up to give the student practice operating the instructional terminal was extremely important. The student was allowed to warm-up on a short section of the modern mathematics course on elementary set theory. During this period a graduate assistant worked with the student at the terminal to clear up any questions or problems he might encounter. A set of directions was also read to the student explaining the general nature of the experiment. Immediately following the warm-up period, the student was administered a pretest to measure his previous knowledge of the subject matter area in which he would be given instruction that same evening. Later the same day at approximately 6:30 p.m., the student returned for instruction via CAI on a section of the modern mathematics course designed to teach number systems with bases other than ten. [The first part of this section of the modern mathematics course is shown in Chapter III (p. 11)]. Immediately following instruction at the terminal, the student was given an alternate form of the pretest designed to measure his achievement of course content (hereafter referred to as posttest 1), and was asked to fill out the Student Reaction Inventory. The student returned exactly one week later for session three and at that time took another form of the achievement test (posttest 2) as a measure of retention. Due to an error in procedure, some students were administered posttest 1 a second time while others were given the pretest again as the posttest 2 measure. The original intent was to use the pretest as the delayed retention measure to minimize direct recall of responses given to items in the test. An examination of the students given the different forms of the achievement test as posttest 2 shows no differences in their performance as a function of the form of the test used.

## Reliability of the Achievement Measures

As mentioned above, an important aspect of research on CAI is the development of good achievement tests and other criterion measures to evaluate the outcome of such instruction. Several short achievement tests were developed in the present project, one to measure achievement in the audiology course, and two alternate forms of a test to measure achievement in the use of number systems with bases other than ten (see Appendix A, p. 93). Each form of the modern mathematics test was 23 items in length. Reliability of the test was evaluated by means of the Hoyt analysis of variance technique (Hoyt, 1941).

The analysis of variance summary for the sample of 20 students on Form B is shown in Table 3 below. The reliability of the test as estimated by the formula $r_{tt} = 1 - \frac{\text{M.S. residual}}{\text{M.S. between } \underline{\text{Ss}}}$ is shown directly beneath the table to be .93.

Since the subjects in the present sample were selected as extreme high and low aptitude groups, the possibility exists that the above reliability coefficient is spuriously high due to the exclusion of students of average aptitude. In order to check this possibility, separate estimates of reliability were obtained within the high aptitude and low aptitude groups. If the range of scores on the achievement test had been seriously inflated by using extreme aptitude groups, one would expect the reliabilities computed separately within the restricted range of high and low aptitude groups to be substantially lower than the reliability for the entire group.

TABLE 3

Analysis of Variance Reliability of Form B of the
Modern Mathematics Achievement Test for the
Total Group of 20 Students

| Source | SS | df | MS |
|---|---|---|---|
| Between Ss | 39.52 | 19 | 2.08 |
| Within Ss | 67.65 | 440 | |
| Items | 11.17 | 22 | .51 |
| Residual | 56.48 | 418 | .14 |
| | | 459 | |

$$r_{tt} = 1 - \frac{.14}{2.08} = .93$$

Tables 4 and 5 show the analyses of variance estimates of reliability for the 12 high aptitude students and 8 low aptitude students respectively. As can be seen from the tables, the reliabilities were .92 and .94 for the high and low SAT groups respectively indicating that the use of extreme groups had no effect on the reliability estimate for the achievement test.

TABLE 4

Analysis of Variance Reliability of Form B of the
Modern Mathematics Achievement Test
for the Group of 12 High SAT Students

| Source | SS | df | MS |
|---|---|---|---|
| Between Ss | 18.98 | 11 | 1.73 |
| Within Ss | 37.83 | 264 | |
| Items | 5.98 | 22 | .27 |
| Residual | 31.85 | 242 | .13 |

$$r_{tt} = 1 - \frac{.13}{1.73} = .92$$

TABLE 5

Analysis of Variance Reliability of Form B of the
Modern Mathematics Achievement Test for the
Group of 8 Low SAT Students

| Source | SS | df | MS |
|---|---|---|---|
| Between Ss | 16.15 | 7 | 2.31 |
| Within Ss | 29.83 | 176 | |
| Items | 9.98 | 22 | .45 |
| Residual | 19.85 | 154 | .13 |

$$r_{tt} = 1 - \frac{.13}{2.31} = .94$$

The prior reliabilities reflect a high level of internal consistency of the test. Some evidence on the stability of performance on the modern mathematics achievement test is available from the correlation between the posttest 1 and posttest 2 administrations over a one week interval. The latter correlation was .93. Owing to a highly restricted range of scores on the pretest (students showed very little prior knowledge of number systems with bases other than ten), no meaningful correlation between the pre- and posttests could be computed.

## Results

The results are reported in the form of two analyses. The first analysis shown in Table 6 (p. 85) shows t tests comparing the means of the high versus low SAT groups on a number of performance and attitude ratings. The reader should note that the series of t tests reported in Table 6 is not the most ideal statistical analysis for these data since some of the dependent variables are correlated and thus provide partially redundant information. Owing to the small samples of subjects, and the preliminary nature of the data, appropriate multivariate analyses were considered uneconomical at the present time. A correlational analysis was also computed showing some of the same relationships shown in the table of t tests, and in addition, relationships between a number of other variables. The results of the correlational analysis are shown in Tables 7 and 8 (pp. 86,89).

The results of the t test analysis generally indicate that the high aptitude group performed better and had more positive attitudes toward CAI than the low aptitude group. Although the groups differed significantly on the pretest, the mean performance of both groups was less than one item correct out of 23. It can be concluded that the students in the sample had very little prior information about number systems with bases other than ten. Although the posttest achievement scores and other performance measures were not significantly different for the two groups, every difference was in the expected direction. The high SAT group had higher mean achievement posttest scores, and lower mean number of errors, time to complete the material, and number of remedial questions encountered in the course than the low SAT group. In general, the high aptitude subjects evidenced more positive attitudes towards CAI than the low aptitude subjects. The mean ratings for the high SAT Ss were more positive than those of the low aptitude Ss on 12 of the 13 scales. The statistically significant differences indicate that the high SAT group had higher means than the low group on the scales Bad-Good, Unfair-Fair, and Difficult-Easy (as might be expected). The low group also reported that they more frequently missed opportunities for discussion during instruction at the CAI teaching terminal. The most likely interpretation of the differences in attitudes of the high and low aptitude groups is that poorer performance produces more negative attitudes towards the instructional method regardless of what method is being used. The students are probably reacting to their own performance rather than to the method of instruction as such. Since aptitude correlates positively with performance in the course, the differences in mean ratings cannot be attributed to aptitude alone. Some partial correlations holding performance constant are reported below in an attempt to support the above interpretation. Other results from the correlational analysis support the interpretation that poor performance produced the negative rating rather than the other way around.

A comparison of the mean posttest 1 and delayed posttest 2 scores indicates that no forgetting took place over the one week interval. The total group mean for posttest 1 was 14.7, while the mean for the one week delayed test was 15.0. This lack of evidence for forgetting after one week is probably not due to any unique advantage of computer-assisted instruction in facilitating retention, but rather to the nature of the learning task used in the study. Manipulating number systems with bases other than ten involves learning a set of principles which, once mastered, are probably not easily forgotten. In fact, the principles learned are the same principles used implicitly by all students in working with the base ten or decimal system. Once the student learns to apply the rules with number systems having bases other than ten, his vast experience with the decimal system most likely facilitates retention.

Table 7 (p. 86) shows the matrix of intercorrelations for the Scholastic Aptitude Test scores and the CAI performance measures. It should be remembered that the use of extreme groups on the aptitude measure would tend to inflate correlations over what would be obtained if the

## TABLE 6

### Comparisons of High and Low Aptitude Groups (as Measured by the SAT) on CAI Attitude and Performance Variables

| Variable | Low SAT (n=8) X | High SAT (n=12) X | t | P |
|---|---|---|---|---|
| Pretest | 0.12 | 0.83 | + 2.20 | .05 |
| Posttest 1 | 12.0 | 16.50 | + 1.49 | |
| Posttest 2 | 13.6 | 15.9 | + .70 | |
| SAT V | 420.9 | 607.5 | +10.90 | .001 |
| SAT M | 479.3 | 541.5 | + 1.81 | .10 |
| Ratings of Course: | | | | |
| Fast | 3.9 | 4.0 | + .14 | |
| Interesting | 5.2 | 5.3 | + .10 | |
| Relaxed | 3.6 | 4.8 | + 1.08 | |
| Good | 3.5 | 5.2 | + 2.14 | .05 |
| Fair | 3.8 | 5.9 | + 2.42 | .05 |
| Deep | 4.8 | 4.3 | .51 | |
| Valuable | 4.4 | 5.1 | + .80 | |
| Active | 4.5 | 4.9 | + .43 | |
| Easy | 2.2 | 4.4 | + 2.85 | .02 |
| Flexible | 3.2 | 4.3 | + 1.53 | |
| Machine Fast | 4.6 | 5.3 | + .67 | |
| More attention to machine | 4.0 | 6.1 | + 1.66 | |
| Did not miss opportunities for discussion | 3.1 | 5.5 | + 2.21 | .05 |
| Total Errors | 35.0 | 24.2 | 1.36 | |
| Content Errors | 30.6 | 21.2 | 1.37 | |
| Form Errors | 4.4 | 3.0 | 1.08 | |
| Mean Time | 206.1 | 179.5 | 1.13 | |
| Mean No. Remedial Questions | 53.5 | 48.9 | .45 | |

### TABLE 7

### Correlations Among Scholastic Aptitude Test (SAT) and CAI Performance Measures (n=20)*

| | SAT U | SAT M | Posttest 2 | Delayed Posttest 2 | Errors | Time | Remedial Questions |
|---|---|---|---|---|---|---|---|
| Verbal SAT | | .50 | .45 | .24 | -.41 | -.10 | -.18 |
| Math. SAT | | | .47 | .51 | -.37 | -.07 | -.18 |
| Posttest 1 | | | | .93 | -.93 | -.49 | -.79 |
| Delayed Posttest 2 | | | | | -.87 | -.50 | -.77 |
| Errors made in program | | | | | | .55 | .81 |
| Time to complete course | | | | | | | .55 |

$^*r_{.05} = .44$

$r_{.01} = .56$

entire range of aptitude scores had been used. The extreme high and low aptitude groups used in the present preliminary analysis were selected as part of a larger experiment designed to investigate interactions between student ability and course sequencing variables. Although the present correlations may be spuriously high, they provide important preliminary information concerning the nature of the relationships between the variables.

As can be seen in Table 7, correlations between the SAT scores and the two achievement posttest scores ranged from .24 to .51. The correlations of the verbal and mathematical SAT scores with the numbers of errors made in the program were -.41 and -.37 respectively. These correlations fall within the range of magnitude of correlations usually obtained between measures of scholastic aptitude and school achievement. It is of interest to note that one of the objectives of computer-assisted instruction is to minimize the correlation between student aptitude and the outcomes of instruction by adapting the instruction to the abilities of the learner. Thus, if all students begin to approximate maximum achievement as measured by a criterion test, the correlation between aptitude and achievement would necessarily be decreased. Whether a truly adaptive instructional program can bring all college students to approximately the same level of achievement still remains to be demonstrated.

Another rather revealing set of correlations were those of the achievement criterion tests with errors and the number of remedial questions encountered by the student. The correlations of errors with posttests 1 and 2 were -.93 and -.87 respectively, while the correlations of remedial questions with posttests 1 and 2 were -.79 and -.77 respectively. The correlations between posttests 1 and 2 and errors is surprisingly high in view of the fact that the modern mathematics program included approximately 50 per cent remedial branches designed to clear up student errors. If the remedial sections of the course had been serving their proper function, student errors made in the program would have been corrected by the remedial branch, and the student should not have responded with the same errors on the posttest measure of achievement. If the remedial sections had in fact been correcting student errors, one would have expected a somewhat lower correlation between errors made in the program and errors made on the achievement posttest. The correlation of -.93 suggests that the student who was confused during the actual instruction, remained confused on the achievement posttest. The above interpretation is based on correlational data and small samples and is therefore highly tentative; however, the results do call attention to the problems of evaluating the effectiveness of remedial branching programs for student learning. In the future, we plan to make more specific comparisons between course programs with and without remedial instruction and comparisons of the effects of different types of remedial instruction.

Table 8 (p. 89) shows the correlations between the ratings of attitude towards CAI and the SAT and CAI performance measures. As was seen in the earlier analysis, in general, the higher the SAT and achievement in the course, the more positive the reaction to CAI. The fewer errors and number of remedial questions encountered, and the shorter the time taken to complete the program, the more positive the attitude toward CAI. Although it is difficult to interpret these relationships, it seems most probable that the student is reacting primarily to his own performance in CAI rather than to his liking of CAI as a method of instruction. Several partial correlations were computed between the SAT scores and the Bad-Good rating holding posttest performance constant. When student performance is held constant, the correlations between the SAT scores and the Bad-Good rating decrease and become nonsignificant. In the case of the verbal SAT the correlation dropped from .38 to .17, while for mathematical SAT the correlation dropped from .51 to .34.

Problems in interpretation of self-report data are not uncommon in many different areas of research. The present judgment of the investigators is that the utility of the Reaction Inventory has probably been exhausted. Since self-reports are inexorably entwined with a host of complex effects, it is frequently impossible to determine precisely what the student's self-report is measuring. As demonstrated in the present study, the self-report, rather than measuring the student's attitude toward a method of instruction as such, appears to be measuring his reaction to his own performance. If this is the case, the self-report is providing very little new information over that of the performance measures. The self-report measure was employed in the present investigation _in lieu of_ the development of more adequate criteria. As such it served its purpose by suggesting hypotheses for further study.

The results of Table 8 (p. 89) also show that the student's ratings on the Shallow-Deep scale and on the Difficult-Easy scale appear to reflect his perception of the difficulty of the course. Both scales appear to correlate with aptitude and performance in the expected directions.

Several findings obtained with the second sample of students bear on some earlier results obtained with the initial group of 47 students. The reader will recall that a fairly large percentage of students reported being slightly tense during the first hour of instruction in the first sample. In analyzing the data for the second sample, essentially zero correlations were obtained between performance in CAI and the Tense-Relaxed rating. So far as this small sample of students is concerned, it appears that whatever the student is reflecting on this scale does not relate to his performance in the course. This finding illustrates another common difficulty with self-report data: what the student says he does and what he does are frequently two different things.

### TABLE 8

### Correlations Among Scholastic Aptitude (SAT), CAI Performance Measures, and Attitudes Toward CAI (n=20)*

| | | Ratings | | | | |
|---|---|---|---|---|---|---|
| | Course "Fast" | Good | Fair | Deep | Valuable | Easy |
| Verbal SAT | -.18 | .38 | .46 | -.39 | .17 | .37 |
| Math. SAT | .06 | .51 | .09 | -.68 | .31 | .26 |
| Posttest 1 | .44 | .55 | .00 | -.47 | .32 | .45 |
| Delayed Posttest 2 | .58 | .49 | -.16 | -.47 | .34 | .44 |
| Errors | -.47 | -.46 | -.06 | .34 | -.20 | -.39 |
| Time | -.51 | -.42 | -.13 | .36 | .11 | -.49 |
| Remedial questions | -.53 | -.29 | .17 | .37 | -.22 | -.30 |

*$r_{.05} = .44$

$r_{.01} = .56$

The correlations of the CAI performance measures with the Slow-Fast rating simply reflects the student's perception of his rate of performance in the course. Thus, the students achieving higher scores on the posttests, making fewer errors in the course, and taking less time to finish the material tend to rate the course as fast compared to students scoring lower on the posttests and making more errors.

One finding of considerable importance relates to results obtained in the initial sample of students. The number of correct answers entered in wrong form was found to correlate -.80 with performance on the achievement posttest in the second sample. It was tentatively concluded in the earlier study that "bugs" encountered by the student in the course, or correct answers entered in wrong form tended to seriously interfere with student learning. The results for the second sample tend to support this conclusion. The occurrence of wrong form errors tends to encourage content errors (e.g., the two are correlated .79) which in turn tends to produce poor posttest performance (e.g., -.80). These data simply further emphasize the importance of partial answer processing of student responses so that an answer which is correct in its essential elements is accepted as correct by the computer.

Finally, although the numbers in each group are small, it is of interest to compare the distributions of posttest performance for the two high and low aptitude groups. These distributions are shown in Table 9. Perhaps the most striking observation of student performance in CAI is the tremendous variability in performance and the large overlap of the distributions of high and low aptitude Ss. Clearly the majority of Ss in both groups demonstrated considerable learning on the achievement posttest. Only three Ss (one student in the high group) appeared to exhibit little or no learning on the posttest. Nevertheless, the fact that even three students of college level ability seem to exhibit no learning after instruction designed to adapt to individual differences by providing the necessary remedial work is the challenge still facing researchers interested in the problems of student learning in adaptive instructional systems.

TABLE 9

Distributions of Posttest Achievement Scores of High and Low Aptitude Groups

| | Low SAT | High SAT |
|---|---|---|
| 21-22 | | 5 |
| 19-20 | 1 | 2 |
| 18-19 | 1 | |
| 16-17 | 2 | 1 |
| 14-15 | 1 | |
| 12-13 | | 2 |
| 10-11 | | 1 |
| 8-9 | 1 | |
| 6-7 | | |
| 4-5 | | |
| 2-3 | 1 | 1 |
| 0-1 | 1 | |
| | 8 | 12 |

# CHAPTER V

# DEMONSTRATION AND DISSEMINATION

One major purpose of the present project was to provide demonstrations to educators of a functioning prototype of a CAI system, and to disseminate information pertaining to our experience with CAI. This objective was based on the assumption that implementation of educational innovations is more likely to occur as a result of live "hands on" demonstrations given to educators than as a result of other techniques of information exchange. To make some inroads in the problem of information dissemination, the project undertook a large number of live demonstrations of CAI, produced a video-tape demonstration of CAI, prepared several short demonstration courses illustrating different aspects of CAI, presented and published several research reports of preliminary results with CAI, and conducted a conference on the application of CAI to the in-service preparation of teachers. Each of these activities is summarized briefly below.

Although our guestbook contains 83 names of visitors to the CAI Laboratory at Penn State, it is estimated that over 100 individuals have seen a live demonstration of CAI at the laboratory. These individuals possessed many different backgrounds of experiences such as educator, psychologist, State Director of Vocational Education, writer, Director of Teacher Education, Professor of Engineering, Professor of Mathematics, physiologist, sociologist, counselor, and professionals from Denmark, Australia, and other western nations have been among our most interested visitors. Many of the demonstrations have promoted much stimulating discussion concerning the potential sins and virtues of CAI as it could be employed in a variety of educational situations.

In addition to the live demonstrations, the writers in cooperation with the Instructional Television Services of The Pennsylvania State University produced a video-tape demonstration of a student working at the CAI teaching terminal. This video-tape is shown regularly to introductory educational psychology courses which prepare several hundred potential teachers per term. The taped demonstration was also shown to a conference in continuing education and to a group at the United States Office of Education in Washington.

Several short demonstration courses have been prepared to illustrate various capabilities of CAI to the visitor. The courses may be briefly described as follows:

Msmtdmo 1 - a short segment of material covering several elementary concepts of educational measurement. The demonstration illustrates various capabilities of the slide projector and tape recorder units.

Caexpl - a short section of course material in cost accounting designed to illustrate partial answer processing of relatively long student responses.

The following papers have been presented reporting preliminary results obtained during the first 15 months of the present CAI project:

Wodtke, Kenneth H. and Mitzel, H. E. Some preliminary results on the reactions of students to computer-assisted instruction. A paper presented at the IBM Conference on Computer Assisted Instruction, T. J. Watson Research Center, Yorktown Heights, N. Y., February 2, 1965.

Wodtke, Kenneth H., Mitzel, H. E., and Brown, B. R. Some preliminary results on the reactions of students to computer-assisted instruction. A paper presented at the Pennsylvania Educational Research Association, University of Pittsburgh, April, 1965.

Wodtke, K. H., Mitzel, H. E., and Brown, B. R. Some preliminary results on the reactions of students to computer-assisted instruction. Proceedings of the American Psychological Association, 1965. In press. Paper will be read at the 1965 APA meetings.

Finally, a conference was held at Penn State on April 6, 1965, to discuss the application of computer-assisted instruction to in-service preparation of Pennsylvania teachers of modern mathematics. A current problem in the area of mathematics instruction is that of updating the preparation of teachers in the "new mathematics." Existing in-service preparation methods are slow and frequently only reach a small percentage of teachers. During the above conference, members of the Penn State CAI project discussed with educators from the Pennsylvania Department of Public Instruction the possibilities of providing such instruction by means of remote CAI teaching stations placed at strategic locations throughout the state. Although there are a number of problems still to be worked out concerning the practical application of CAI, it was the general impression of the conference that such an application was feasible; and planning talks are now underway to implement the use of the CAI course in modern mathematics for the in-service education of elementary school teachers.

# APPENDIX A

Student Reaction Inventory

Modern Mathematics Achievement Test, Form A

Modern Mathematics Achievement Test, Form B

Audiology Achievement Test

# STUDENT REACTION INVENTORY

Directions: Now that you have been working with computer-guided instruction for some time, we are interested in getting your reactions to the courses and equipment you have been using. The following are a list of attitude scales and questions designed to measure some of your reactions to computer-guided instruction. Notice that in Part (1) you are to focus on your reactions to the actual content of the course being presented via the typewriter terminal. The scales consist of pairs of bi-polar adjectives which define opposite ends of the rating scales. Your job is to simply circle the position along each scale which best represents your attitude towards the programed course. Try to be as frank as possible. Your questionnaire will be identified by student number, thus you need not put your name on these sheets. Your responses will be used in research into various aspects of the programed courses, and to help us improve and revise existing course materials. Some writing space has been left between each of the rating scales. This space is for any explanation you care to give concerning one of your responses.

Part (2) consists of an equivalent set of scales. In Part (2) we would like you to focus primarily on your reactions to the machinery or equipment used to present the course material. For example, if you thought that the equipment was very difficult to operate, you would respond appropriately on the scale entitled "easy-difficult." Space has again been provided between the scales for clarification or comments concerning your response.

Part (3) consists of a series of additional scales and questions concerning various aspects of computer-guided instruction. The project staff extends their thanks for your cooperation in this research project. Your response will be a great help to us in determining the feasibility of this method of teaching college courses.

Course Name ______________________________

Student Number ___________________________ Date _______________

Part (1): Reactions to content of programed course.

| | extremely | quite | slightly | neutral | slightly | quite | extremely | |
|---|---|---|---|---|---|---|---|---|
| fast | : | : | : | : | : | : | : | slow |
| dull | : | : | : | : | : | : | : | interesting |
| tense | : | : | : | : | : | : | : | relaxed |
| good | : | : | : | : | : | : | : | bad |
| unfair | : | : | : | : | : | : | : | fair |
| deep | [illegible] | : | : | : | : | : | : | shallow |
| valuable | : | : | : | : | : | : | : | worthless |
| active | : | : | : | : | : | : | : | passive |
| easy | : | : | : | : | : | : | : | difficult |
| inflexible | : | : | : | : | : | : | : | flexible |

Part (2): Reactions to machinery or equipment, typewriter terminal, etc.

| | extremely | quite | slightly | neutral | slightly | quite | extremely | |
|---|---|---|---|---|---|---|---|---|
| fast | : | : | : | : | : | : | : | slow |
| dull | : | : | : | : | : | : | : | interesting |
| tense | : | : | : | : | : | : | : | relaxed |
| good | : | : | : | : | : | : | : | bad |
| unfair | : | : | : | : | : | : | : | fair |
| deep | : | : | : | : | : | : | : | shallow |
| valuable | : | : | : | : | : | : | : | worthless |
| active | : | : | : | : | : | : | : | passive |
| easy | : | : | : | : | : | : | : | difficult |
| inflexible | : | : | : | : | : | : | : | flexible |

Part (3):

Have you had any previous typing experience? (Yes or No) ____________________

How would you rate your own typing skill? Assume that average typing speed is about 40 to 50 words per minute.

|  | extremely | quite | slightly | average | slightly | quite | extremely |  |
|---|---|---|---|---|---|---|---|---|
| fast | : | : | : | : | : | : | : | slow |

Do you feel that your typing skill was a help or hindrance to your learning at the computer terminal?

|  | extremely | quite | slightly | neutral | slightly | quite | extremely |  |
|---|---|---|---|---|---|---|---|---|
| hindrance | : | : | : | : | : | : | : | help |

Did you find the machine itself an obstacle or an aid to learning?

|  | extremely | quite | slightly | neutral | slightly | quite | extremely |  |
|---|---|---|---|---|---|---|---|---|
| obstacle | : | : | : | : | : | : | : | aid |

Please explain:

If you had your choice, would you be favorably or unfavorably disposed towards taking this course via computer-guided instruction rather than by traditional instructional procedures?

|  | extremely | quite | slightly | neutral | slightly | quite | extremely |  |
|---|---|---|---|---|---|---|---|---|
| favorable | : | : | : | : | : | : | : | unfavorable |

Explain:

How long do you feel you could work efficiently in computer guided instruction at one sitting? (circle one)

half hour     1 hour     1 1/2 hours     2 hours     More than 2 hours

(approx. how many hours. ________)

Compared to classroom lecture, I was able to give the machine: (circle one)

| | |
|---|---|
| much more attention | about the same degree of attention |
| more attention | slightly less attention |
| slightly more attention | less attention |
| much less attention | |

To what extent did you feel that you had typed in correct answers which were not recognized by the computer?

| | extremely | quite | slightly | neutral | slightly | quite | extremely | |
|---|---|---|---|---|---|---|---|---|
| frequently | : | : | : | : | : | : | : | infrequentl |

In view of what you learned on this program how did you feel about the effort you put into it?

| | extremely | quite | slightly | neutral | slightly | quite | extremely | |
|---|---|---|---|---|---|---|---|---|
| dissatisfied | : | : | : | : | : | : | : | satisfied |

In terms of the amount you learned how would you rate this program compared to traditional instruction?

| | extremely | quite | slightly | neutral | slightly | quite | extremely | |
|---|---|---|---|---|---|---|---|---|
| superior | : | : | : | : | : | : | : | inferior |

Please explain:

Was the amount of review provided in the program adequate or inadequate?

extremely quite slightly neutral slightly quite extremely

inadequate : : : : : : : adequate

Do you feel that the display materials, e.g., written display, models, charts, tables, diagrams, etc., were an aid or an obstacle to your learning?

extremely quite slightly neutral slightly quite extremely

aid : : : : : : : obstacle

Please explain:

To what extent did you encounter machine errors or breakdowns?

extremely quite slightly neutral slightly quite extremely

infrequently : : : : : : : often

Did you miss opportunities for discussion of problems?

extremely quite slightly neutral slightly quite extremely

yes : : : : : : : no

Were the number of branches back in the program to review previous questions, responses, or additonal explanatory material adequate?

extremely quite slightly neutral slightly quite extremely

adequate : : : : : : : inadequate

Were the number of branches ahead in the program to more difficult or advanced material adequate?

extremely quite slightly neutral slightly quite extremely

adequate : : : : : : : inadequate

Were there adequate opportunities to reflect and consider the implications of questions and responses?

extremely quite slightly neutral slightly quite extremely

adequate : : : : : : : inadequate

With regard to the subject matter covered, the steps were:

extremely quite slightly neutral slightly quite extremely

simple : : : : : : : difficult

Modern Math (PART I A) Name____________
Date______________ Student Number____________

1. What is 724 (ten) in base eight?

2. What is 2372 (eight) in base ten?

3. What is 321 (five) in base ten?

4. What is 79 (ten) in base five?

5. What is 23 (twelve) in base ten?

6. What is 3T (twelve) in base ten?

7. What is 269 (ten) in base twelve?

8. What is 3 (ten) in base two?

9. What is 10 (ten) in base two?

10. What is 22 (ten) in base two?

11. What does 364 (seven) equal in base 10?

12. What does 324 (eight) equal in base six?

13. What does 115 (fifteen) equal in base ten?

14. What does 2 (eleven) equal in base three?

15. What does 100 (four) equal in base two?

16. What does 225 (seven) equal in base nine?

Modern Math (PART I A) page 2 Name______________
Date________________ Student Number______________

17. How is one of the base always written regardless of the value of the base?

______________________________________________

18. How is one of the base squared always written?

______________________________________________

19. How is one of the base cubed always written?

______________________________________________

20. What is the meaning of the circled numeral? 5 ⑤ 5 5 n

a. 5 x n
b. (5 x 5) x n
c. 5 x (n x n)
d. 5 x (n x n x n)
e. (5 x 5 x 5) x n

______________________________________________

21. What is the meaning of the circled numeral? 1 ⑤ 3 4 2 (six)

a. 5 x 6
b. (5 x 5 x 5 x 5) x 6
c. (5 x 5 x 5) x 6
d. 5 x (6 x 6 x 6 x 6)
e. 5 x (6 x 6 x 6)

______________________________________________

22. What is the "expanded-notation" form of 3 7 2 6 (nine)?

a. (3 x 9 x 9 x 9 x 9) + (7 x 9 x 9 x 9) + (2 x 9 x 9) + (6 x 9)
b. (9 x 3 x 3 x 3) + (9 x 7 x 7) + (9 x 2) + 6
c. (3 x 10 x 10 x 10) + (7 x 10 x 10) + (2 x 10) + (6 x 1)
d. (3 x 9 x 9 x 9) + (7 x 9 x 9) + (2 x 9) + (6 x 1)
e. (10 x 3 x 3 x 3) + (10 x 7 x 7) + (10 x 2) + (10 x 1)

______________________________________________

23. What comes after 3T (eleven)?

______________________________________________

Modern Math (PART I B) Name______________
Date________________ Student Number______________

1. What is 635 (ten) in base eight?

2. What is 3227 (eight) in base ten?

3. What is 213 (five) in base ten?

4. What is 68 (ten) in base five?

5. What is 34 (twelve) in base ten?

6. What is 5T (twelve) in base ten?

7. What is 414 (ten) in base twelve?

8. What is 5 (ten) in base two?

9. What is 15 (ten) in base two?

10. What is 17 (ten) in base two?

11. What does 253 (seven) equal in base 10?

12. What does 435 (eight) equal in base six?

13. What does 226 (fifteen) equal in base ten?

14. What does 5 (eleven) equal in base six?

15. What does 1,000 (four) equal in base eight?

16. What does 336 (seven) equal in base nine?

Modern Math (PART I B) page 2 Name____________
Date_______________ Student Number____________

17. Regardless of the value of the base, 100 is always equal to the base __________. (One word answer).

---

18. Regardless of the value of the base, 10 is always equal to _________ of the base.

---

19. Regardless of the value of the base, 1000 is always equal to the base ____________.

---

20. What is the meaning of the circled numeral?

③ 3 3 3 n

a. 3 x n
b. (3 x 3) x n
c. 3 x (n x n)
d. 3 x (n x n x n)
e. (3 x 3 x 3 x 3) x n

---

21. What is the meaning of the circled numeral?

1 ② 5 3 4 (five)

a. 2 x 5
b. (2 x 2 x 2 x 2) x 5
c. (2 x 2 x 2) x 5
d. 2 x (5 x 5 x 5 x 5)
e. 2 x (5 x 5 x 5)

---

22. What is the "expanded-notation" form of 7 3 2 6 (eight)?

a. (7 x 8 x 8 x 8 x 8) + (3 x 8 x 8 x 8) + (2 x 8 x 8) + (6 x 8)
b. (8 x 7 x 7 x 7) + (8 x 3 x 3) + (8 x 2) + 6
c. (7 x 10 x 10 x 10) + (3 x 10 x 10) + (2 x 10) + (6 x 1)
d. (7 x 8 x 8 x 8) + (3 x 8 x 8) + (2 x 8) + (6 x 1)
e. (10 x 7 x 7 x 7) + (10 x 3 x 3) + (10 x 2) + (10 x 6)

---

23. What comes after 3T (eleven)?

---

CAI Project
Audiology

Name______________
Student Number______________
Date______________

1. What is the name for that part of the external ear most visible, and on the outside of the head?______________
2. What small structure of the ear divides the external ear from the middle ear?______________
3. What passageway connects the pinna or auricle with the tympanic membrane or eardrum?______________
4. What is the name of the substance that is secreted by glands along the external auditory meatus?______________
5. What else does one normally find along the external auditory meatus?

______________

6. What is the name for part A?______________
7. What is the name for part B?______________
8. What is the name for part C?______________
9. What is the name for part D?______________
10. What is the name for part E?______________
11. What is the name for part F?______________
12. What is the name for part G?______________
13. What is the name for part H?______________
14. What do we call part I?______________
15. What is the name for part J?______________
16. What is the name for part K?______________
17. What do we call part L?______________
18. What is the name for part M?______________
19. What do we call the part labeled N?______________
20. Part O is______________

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